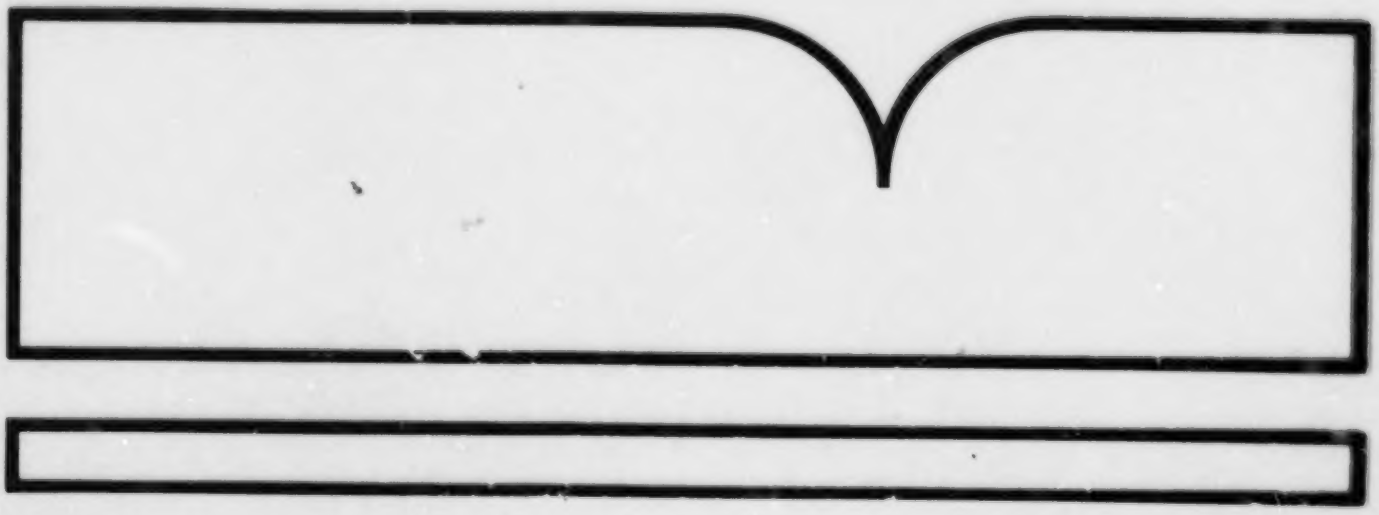
PB85-227908

Low Frequency Automated Magnetic Field Calibration System

(U.S.) Office of Radiation Programs
Las Vegas, NV

Dec 83



U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA 520/6-85-020	2.	3. Recipient's Accession No. PB85 227908/AS
4. Title and Subtitle: A Low Frequency Automated Magnetic Field Calibration System			5. Report Date
			6.
7. Author(s): Arthur P. Ludwigsen			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: U.S. Environmental Protection Agency, Nonionizing Radiation Branch, Office of Radiation Programs, P.O. Box 18416, Las Vegas, NV 89114-8416			10. Project/Task/Work Unit No.
			11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address: SAME			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report describes the construction of an automated absolute magnetic field generation system using a 0.5 meter radius Helmholtz coil. The system operates over a frequency range of dc to 20 kHz and can generate field strengths up to approximately 1 Gauss RMS. The theoretical fields in the region surrounding the coil were calculated and compared with measurement. The system is used for the evaluation of broadband survey meters and calibrated antennas.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
from NTIS	20. Security Class (This Page)	22. Price
		84
		$11.50

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

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United States
Environmental Protection
Agency

Office of Radiation Programs
Nonionizing Radiation Branch
P.O. Box 18416
Las Vegas NV 89114-8416

EPA-520/6-85-020
June 1985

Radiation

EPA

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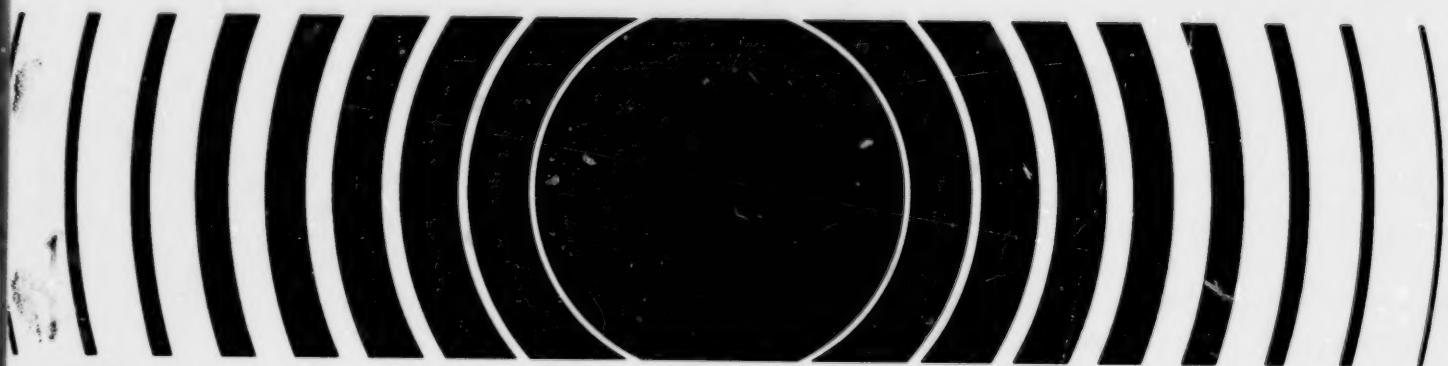

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A Low Frequency Automated Magnetic Field Calibration System

by
Arthur P. Ludwigsen

December 1983

U.S. Environmental Protection Agency
Nonionizing Radiation Branch
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DISCLAIMER

Although the work described in this document has been funded wholly by the United States Environmental Protection Agency it has not been subjected to the Agency's required peer and policy review and therefore does not necessarily reflect the views of the Agency. No Official endorsement should be inferred.

FOREWORD

The Environmental Protection Agency, Nonionizing Radiation Branch is in the process of developing guidance for acceptable environmental levels of electromagnetic radiofrequency radiation. This guidance should recommend which available instrumentation is to be used to measure field strengths. Thus, it is necessary to develop systems for the evaluation of these hazard meters. This report document one system, the EPA automated Helmholtz coil system as used to evaluate broadband survey meters in the frequency range of 0 (DC) to 20 kHz.

Office of Radiation Programs

ABSTRACT

This design project was initiated with the overall objective of creating an automated Helmholtz coil magnetic field calibration system. This system is to be used in the evaluation of broadband survey meters and calibrated antennas which are employed for environmental measurements of low frequency magnetic fields.

Expressions for the magnetic field in a Helmholtz coil are developed to include calculation of the field in off-axis positions. Measurements were made of the field at various points and compared with theoretical predictions.

The system layout, programming and operation are documented to show how frequency, field strength, and evaluation of the tested object are controlled.

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ACKNOWLEDGEMENT

I would like to thank Edwin D. Mantiply and Paul Gailey for their many useful suggestions during the development of this system and Michael Molony for his programming assistance.

EXECUTIVE SUMMARY

The Nonionizing Radiation Branch of the Office of Radiation Programs, U.S. Environmental Protection Agency, is responsible for establishing guidance levels for public exposure to electromagnetic radiofrequency radiation. It also maintains a laboratory to develop and apply systems for the evaluation of field strength measurement instruments. This project consisted of the design of one system, the EPA Automated Helmholtz coil System, that is to be used to evaluate broadband survey meters in the frequency range of 0 to 20 kHz.

The Helmholtz coil system had the following requirements:

1. Generation of stable magnetic fields with intensities up to 1.0 G
2. Frequency range between 0 and 20 kHz
3. Manual or computer control of the system
4. Ability to evaluate broadband measurement instruments and calibrated antennas.

Construction of the system and initial testing has been completed. Initial testing revealed some areas which warrant further study. The automation program has been written and tested. A theoretical characterization of the Helmholtz coil has been completed but further interpolation is needed to smooth out the data. A four-terminal shunt resistor is being purchased and will need to be characterized over the power and frequency range of the system so that accurate current measurements can be made. Further study is needed of the system to determine its operating characteristics over long periods.

INTRODUCTION

The Nonionizing Radiation Branch of the Office of Radiation Programs, U.S. Environmental Protection Agency, is responsible for establishing safe and reasonable standards for public exposure to nonionizing radiation. As a corollary to this responsibility, the Branch has the capability to make field strength measurements to determine environmental exposure levels of the public. The Branch also maintains a laboratory in Las Vegas, Nevada, to develop techniques to evaluate the error associated with both measurement instruments and measurement techniques.

The low frequency magnetic field calibration system discussed in this report was designed to calibrate and evaluate instruments operating at frequencies between zero (DC) and 20 kHz. This system is one part of a project to expand the Branch's instrument evaluation capability into the low frequency area. The magnetic field calibration system will:

1. generate stable magnetic fields from 0.5 milliGauss (mG) to 1.0 G with a precision of ±0.05 mG,

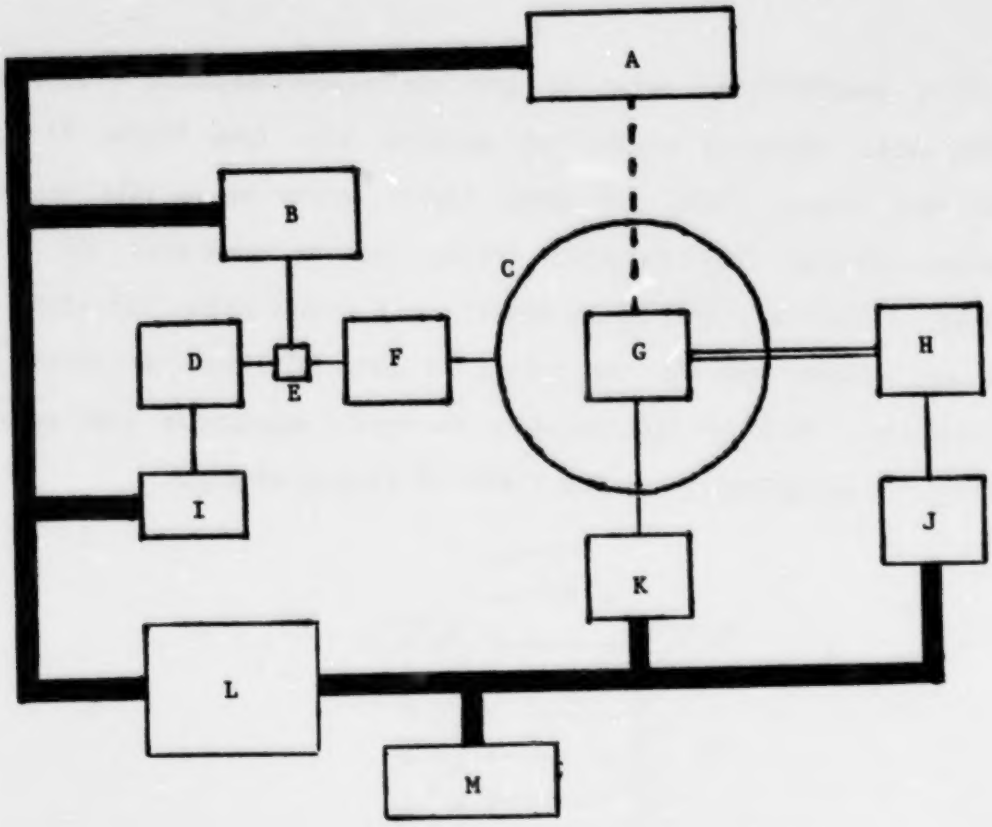
2. have a frequency range between zero and 20 kHz,

3. be capable of manual or automatic control, and

4. be able to evaluate broadband field strength measurement instruments and calibrated antennas to determine overall bandwidth, resonant frequencies, and other characteristics of the instruments or antennas.

To accomplish these objectives, the system configuration illustrated in Figure 1 was implemented. The magnetic field is generated by amplifying an low level input signal (either discrete frequencies or a broadband signal) as necessary and delivering it to a Helmholtz coil that generates magnetic fields. The instrument or antenna being tested is placed in the magnetic field and it's output compared to the value of the established field. This measurement can also be observed as a function of time or angular position relative to the field orientation. The difference between the measured and established values is the error and is used to correct readings from that instrument or antenna when it is used for on-site field measurements

The process is automated by using a controller program specially written as part of this project. This program computes the frequencies and voltage levels needed by the system, generates the magnetic field, and evaluates the instrument or antenna being tested. This process is completely automated and, once the operator starts the program, will free the operator for other work activities.



Bold lines are data transfer and computer command lines.
Thin lines are signal lines. Double line indicates extension from rotator.

A. HP 3582A Spectrum Analyzer
B. HP 3490A Digital Multimeter
C. Helmholtz Coil
D. Crown M600 Amplifier
E. 0.1 Ω Current Shunt
F. 2.0 Ω Resistive Load
G. Instrument Being Tested
H. Rotator
I. HP 3314A Signal Generator
J. HP 59309A Relay Actuator
K. HP 59313A A/D Convertor
L. HP 9845B Computer
M. HP 2631G Graphics Printer

Figure 1. Block diagram of low frequency magnetic field calibration system

MAGNETIC FIELD GENERATION DEVICE

Various possibilities exist to generate stable magnetic fields for laboratory use. Opposing magnets of opposite sign (see Figure 2) will generate very strong fields but these fields cannot be quickly changed. Alternating current (AC) magnetic fields can be generated by using electro-magnets but the core of the magnet would remain magnetized after the current was stopped due to the nature of materials used as cores for electro-magnets. This inherent tendency to remain magnetized also creates difficulties in establishing magnetic fields of varying strength.

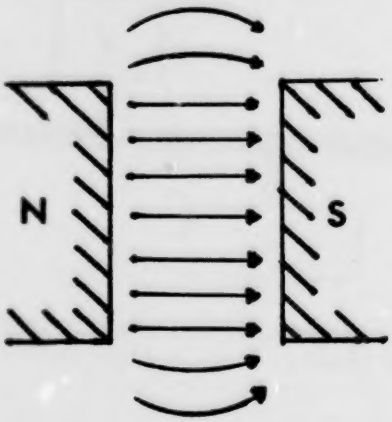


Figure 2. Diagram of opposing magnets and magnetic field

A Helmholtz coil is used in this project to generate the magnetic fields. The Helmholtz coil consists of two identical loops of wire. This device creates fields according to the Biot-Savart Law [1]:

$$dB = \mu_0 I \, dl \times r \qquad (1)$$

where B is the magnetic field measured in Teslas, μ_0 is the magnetic

permeability of free space ($4\pi x10^{-7}$ Tesla·meter/ampere), I is the current through the coil is amperes, dl is the infinitesimal length of current in meters, and r is the distance to the point where the magnetic field is being calculated in meters. There are several advantages to using a Helmholtz coil. Theoretical calculations discussed later show that the magnetic field of interest varies less than 5 per cent within an imaginary cylinder centered in the coil with a radius one-half that of the coil and capped by the rings of the coil. Designing and building a Helmholtz coil is also a very simple process.

The coil used in this project has an added feature of arbitrary orientation in space, that is, it can be pointed in any desired direction. This is done by using wheels at the base of the coil support stand to permit rotation about a vertical axis. Pivots at opposite points on the circumference of the coil permit rotation about a horizontal axis.

The coil has a diameter of one meter and, with the exception of the wire coil and the wheels at the base, is made entirely from wood. The size was dictated by a compromise between available laboratory space and the need to have a sufficiently large volume magnetic field in which to place test instruments and antennas. Wood was used for the ring support and stand because it has virtually no magnetization, is easily worked, and was readily available at low cost.

The wire support, illustrated in Figure 3, is made from two rings of one-half inch plywood separated by one inch dowels and 2 x 4's at the pivot areas. The plywood rings have a one meter outside diameter and are 10 cm thick with a groove for the wire cut into the outside of the ring. The dowels

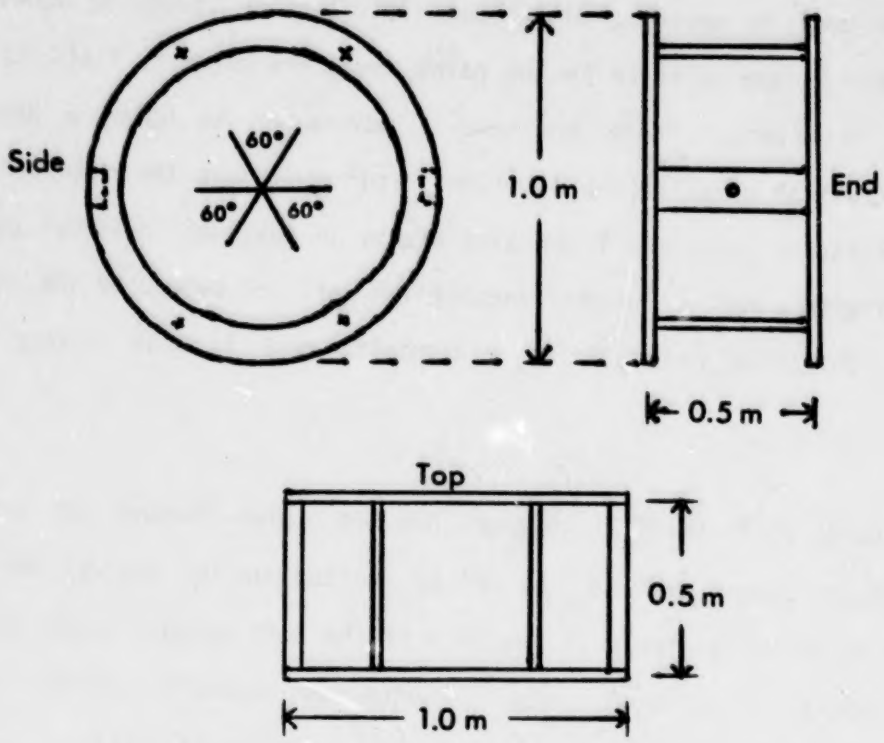


Figure 3. Helmholtz coil wire support

and 2 x 4's are approximately 50 cm long and are trimmed so that the ring to ring separation is 50 cm when assembled as measured from the centers of the rings. The support stand, shown in Figure 4, is made from 2 x 4's also with a 4 x 4 main beam that has a mounting hole in the center and is braced for rigidity. The pivots from the wire support ring are mounted through the top of the support stand risers. All joints are either butt or tongue joints with glue and 1/4 inch dowels for fastening.

Three turns of number 10 gauge solid wire are wound on each support ring. The number of turns selected was based on the desired dynamic range in field amplitude, the output capabilities of the amplifier, and the value of the resistive load. The final selection of three turns per ring will generate

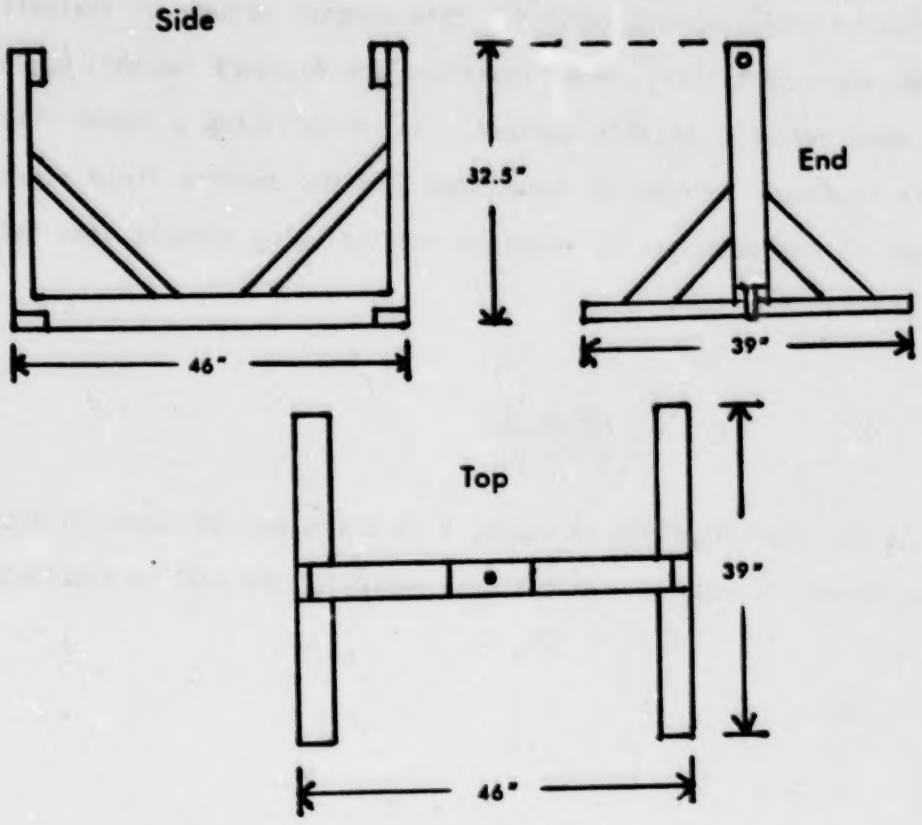


Figure 4. Helmholtz coil support stand

a 1.0 gauss RMS field with a coil current of 18.5 amperes and results in only 17.8 microhenries inductance. A low inductance is desired to reduce the possibility of a resonant frequency within the test frequency range due to stray capacitances within the system and to reduce inductive reactance that would change the impedance of the system, which is approximately 2 ohms resistive, thereby changing the current through the coil and the magnetic field that is generated.

Measurement of the current through the coil will be made by measuring the voltage across a 0.1 ohm ± 0.1 percent 4-terminal shunt resistor in series with the coil. The original concept was to use the amplifier's resistive load

to measure the current but the results of a characterization of the load showed that it would be unreliable for this purpose because of instablity due to thermal characteristics. Shunt resistors are designed for this application and are more reliable in this context. In establishing a field within the coil, the necessary current is calculated for the desired field strength at the center of the coil and is based on the following formula from Reitz and Milford [2]

$$B = \frac{32\pi N}{5^{1.5} a} \frac{I}{10} \tag{2}$$

where B is the magnetic field in Gauss, N is the number of turns on each ring, I is the current in amperes, and a is the radius of the coil in centimeters.

CHARACTERIZATION OF THE HELMHOLTZ COIL

A theoretical characterization was made of the Helmholtz coil based on the following series expansion from Jackson [3] of the Biot-Savart Law for a loop of wire.

$$B_r = \frac{2\pi Ia}{cr} \sum_{n=0}^{\infty} \frac{(-1)^n\ (2n+1)!!}{2^n\ n!} \frac{r_<^{2n+1}}{r_>^{2n-1}} P_{2n+1}(\cos\theta) \tag{3}$$

$$B_\theta = \frac{-\pi Ia}{c} \sum_{n=0}^{\infty} \frac{(-1)^n\ (2n+1)!!}{2^n (n+1)!} \left\{ \begin{matrix} -\left(\frac{2n+2}{2n+1}\right) \frac{1}{a} 3 \left(\frac{r}{a}\right)^{2n} \\ \frac{1}{r} 3 \left(\frac{a}{r}\right)^{2n} \end{matrix} \right\} P^1_{2n+1}(\cos\theta) \tag{4}$$

where $(2n+1)!! = (2n+1)(2n-1)(2n-3) \ldots (5)(3)(1)$. In the first equation, $r_<$ ($r_>$) is the smaller (larger) of a and r. In the second equation, the upper line holds for $r < a$ and the lower line for $r > a$. These formulas are based on the polar coordinate system shown in Figure 5. The Legendre polynomials

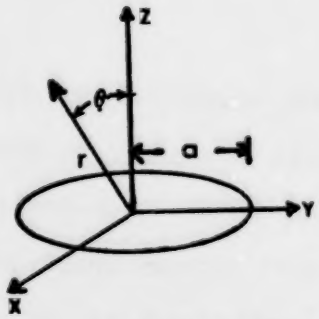


Figure 5. Coordinate system used in Jackson formulas

$P_{2n+1}(\cos\theta)$ and $P^1_{2n+1}(\cos\theta)$ can be expanded for numerical analysis as shown by NBS [4] and Cushing [5].

$$P_n(x) = [(2n-1)P_{n-1}(x) - (n-1)P_{n-2}(x)]/n \quad (5)$$

$$P_n^1(x) = \frac{(n-1)}{(1-x^2)^{1/2}} [xP_n(x) - P_{n+1}(x)] \quad (6)$$

where $P_n(x)$ is the nth term of the Legendre polynomial of x and $P_n^1(x)$ is the nth term of the first associated Legendre polynomial.

For a Helmholtz coil, the magnetic field through the coil and away from the coil are summations of contributions from each ring as shown in the following expressions:

$$B_z = B_{r1}\cos\theta_1 + B_{r2}\cos\theta_2 + B_{\theta 1}\sin\theta_1 + B_{\theta 2}\sin\theta_2 \quad (7)$$

$$B_r = B_{r1}\sin\theta_1 + B_{r2}\sin\theta_2 - B_{\theta 1}\cos\theta_1 - B_{\theta 2}\cos\theta_2 \quad (8)$$

where B_{r1} and $B_{\theta 1}$ are contributions from one ring and B_{r2} and $B_{\theta 2}$ are contributions from the other ring. θ_1 and θ_2 are the angles from the central axis as seen by each ring. B_z constitutes the magnetic field parallel to the axis of the Helmholtz coil and B_r is the field perpendicular to the axis.

As can be seen from the equations, the Jackson formulas [3] are not precise for r = a but do lend themselves to numerical methods and computer analysis. The program FIELDS, listed in Appendix A, was written to compute the magnetic field with the coil current normalized to one ampere. Since the magnetic field is directly proportional to the current in the coil, other field strengths at different currents can be easily interpolated. The program INTERP was written to account for values were r = a or where the FIELDS program did not converge within the specified number of interations. This program, which uses natural cubic spline interpolation is also listed in

Appendix A. Examination of the data generated by this program shows apparent inconsistencies in the radial component of the magnetic field (B_r). Further work using spline interpolation will be necessary to smooth out the data.

This particular method of calculating the magnetic field in a Helmholtz coil was compared with another method based on Reitz and Milford [6] where elliptic integrals were numerically integrated. Both methods compared well as can be seen in Table 1 using the coordinate system in Figure 6 where the two different methods are calculated using three different machines. These different methods vary by less than 0.1 per cent from each other in comparisons of the dominant field vector at a particular point and by less than 0.5 per cent in comparisons of the less dominant field vector.

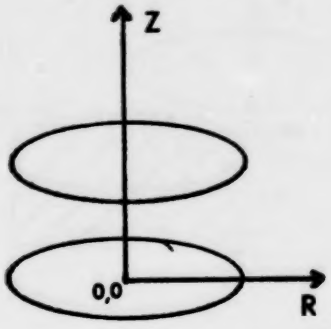


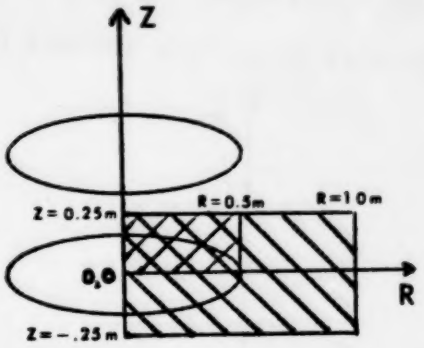
Figure 6. Coordinate system used in Tables 1 and 2

Table 1

R (m)	Z (m)	HP 15C * B_z (mG)	HP 15C * B_r (mG)	HP 9845B * B_z (mG)	HP 9845B * B_r (mG)	HP 9845B ** B_z (mG)	HP 9845B ** B_r (mG)
0.4	0.14	60.1812	-20.9562	60.2183	-20.9562	60.1760	-20.9556
0.4	0.1	60.1812	20.9562	60.2183	20.9562	60.1760	20.9556
0.1	0.4	54.0200	0.4441	54.0183	0.4441	54.0197	0.4467
0.25	0.25	52.1505	0.0	52.1502	0.0	52.1485	0.0
0.0	0.25	53.9505	0.0	53.9506	0.0	53.9545	0.0

* Numerical Integration from Reitz and Milford [6]
** Legendre Polynomials from Jackson [3]

Partial results of this characterization are listed in Appendix B for an area from the center of the coil to a radius of 0.5 m and from the plane of one ring to the center of the coil (see Figure 7). Measurement of the magnetic field in this quadrant adequately characterizes the field anywhere within the Helmholtz coil since the magnetic field is cylindrically symmetric about the z-axis and reflectively symmetric about a plane centered between the two coils and parallel to the coils. That is, the magnetic field at a given radius from the z-axis remains constant at any point on a ring of that radius about the z-axis. Additionally, the field has the same magnitude at points at a given distance above or below a central plane parallel to the coils.



Area studied

Area listed in Appendix B

Figure 7. Area of characterization of Helmholtz coil

Preliminary measurements at random points using a F. W. Bell Gaussmeter show good agreement with the predicted values (see Table 2). These measurements were conducted using a 200 Hz sinusoidal signal at 10 V rms. The differences between the predicted values and the measured ones are attributed to the inaccuracies in trying to measure a free points changes rapidly and so even a 5 mm error in measurement of distance produces a much different

predicted value. For example, if z = 0.1 m, the predicted magnetic field B_z is reduced from B_z = 0.3672 G at r = 0.48 m and z = 0.10 m to B_z = 0.1069 G at r = 0.52 m and z = 0.10 m. This is a 70 per cent change in the magnetic field over a distance of 4 cm. The coordinate system used is shown in Figure 6.

Table 2

R (m)	Z (m)	Bz (Gauss) Predicted	Measured	Per Cent Delivery	Br (Gauss) Predicted	Measured	Per Cent Delivery
0.0	0.0	0.5103	0.500	2.02	0.0	0.0	
0.0	0.25	0.5395	0.530	1.76	0.0	0.0	
0.23	0.125	0.5562	0.470	15.50	0.0133	0.0	
0.4	0.1	0.6018	0.505	16.09	0.2095	0.185	11.69
0.4	0.25	0.3956	0.335	15.32	0.0	0.0	
0.5	0.1	0.2323	0.155	33.28	0.4738	0.485	2.36
0.5	0.25	0.2051	0.160	22.2	0.0	0.0	

These calculations assume that the feed wires to the coil do not contribute anything to the magnetic field. A study will need to be made to determine how these feed wires affect the uniformity of the magnetic field generated by the Helmholtz coil.

AMPLIFIER AND RESISTIVE LOAD

The driving source for this system is a Crown M600 laboratory amplifier. It is a broadband amplifier with a frequency range of 0 to 50 kHz and a specified output capability of 1300 W RMS into a 4 ohm load. The design criterion for the resistive load called for a peak current output with minimal power dissipation from the load and, originally, a load of 0.5 ohm was selected on the premise that lower resistance means higher current at a given power level. This design was found to be unreliable because the amplifier was frequently tripped into standby by thermal safety cut-outs. After consultation with the manufacturer it was learned that the amplifier reaches a peak power output level for a resistive load between 2 and 3 ohm. Therefore, a 2 ohm load was selected that did generally work satisfactorily. One problem that did occur with the 2 ohm resistive load was that of heat dissipation. Since the design of the resistive load called for it to be enclosed for safety reasons, a heat buildup problem developed. A 20 ampere current through the load dissipated 800 W that had to be removed to prevent heat buildup and a possible fire hazard. This was corrected by ventilating the case of the load and moving it to the top of the equipment rack above the other system components. Additionally, two muffin fans were mounted to the bottom of the load case to move about 150 cfm of air through the case for added cooling.

Preliminary designs for the calibration system called for measurement of the current through the Helmholtz coil as a function of the voltage across the resistive load. Therefore, a characterization of the load was needed to determine its resistance at various frequencies and power levels. This was

accomplished by using two digital multimeters and a 0.001 ohm current shunt as shown in Figure 8. A 15 kHz sinusoidal signal was amplified and passed through the load where simultaneous readings were made on both multimeters.

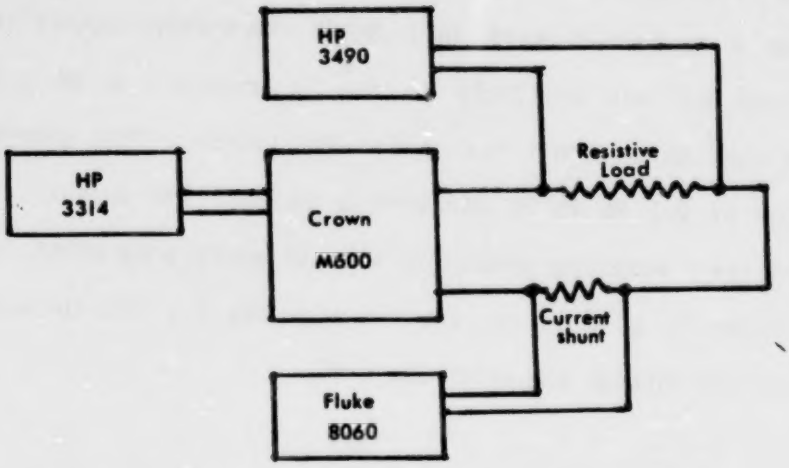


Figure 8. Circuit diagram for resistive load characterization

The results of this study showed that although there were no appreciable effects due to frequency, drastic variations occured when different power levels were applied. The resistance of the load varied from a low of slightly less than 1.8 ohm to a high of about 2 ohm. This 10 percent variation in the load resistance occured mainly when the voltage across the load was between 0 and 10 V, or at currents between 0 and 5 A. Since this is a current range where the system will commonly be used, the variations in load resistance made this design unsuitable for current measurements. As was mentioned earlier, current measurements will be made using a 0.1 ohm current shunt. This will allow accurate current measurements independent of the resistance value of the load due to the design of the current shunt and the method in which it will be used in the system.

OTHER EQUIPMENT

Additional equipment needed for the system are a signal source, a digital multimeter, a spectrum analyzer, and an analog to digital (A/D) convertor, a rotator, and a relay actuator. All of this equipment has to be interactively programable by a Hewlett-Packard (HP) 9845B instrument controller for an automated system and was available in the laboratory. A HP 3314A signal generator was used as a signal source for the system. This generator has a frequency range of 0.1 Hz to 20 MHz with 0 to 10 V RMS output. It is also capable of arbitrary waveform generation when properly programmed. A HP 3490A digital multimeter is used in conjunction with the 0.1 ohm current shunt to measure the current through the Helmholtz coil.

The HP 3582A real-time spectrum analyzer is used when antennas are being evaluated. It has a frequency range from 0 to 25 kHz and will display a signal from an antenna on a cathode ray tube as magnitude plotted against frequency. This analyzer can display magnitude on a linear or logarithmic scale and can determine various characteristics about the input signal such as the transfer function, differences between magnitudes or frequencies, bandwith of a signal, and other characteristics. It is completely interactive with the HP 9845B.

Analog signals from field strength measurement instruments with recorder outputs may be converted to digital values for the computer by a HP 59313A A/D converter. This A/D converter has four input channels, each of which is set to a different full scale value. One channel is reserved for analog inputs with a maximum of one volt, another is used for maximum inputs of 3.5 volts, and one channel samples an output from the rotator to determine position. The

rotator is used to rotate the test instrument relative to the magnetic field so that evaluations can be made on how the instrument operates in different orientations. A HP 59306A relay actuator controls a commercial antenna rotator by outputting a voltage to the porper direction line. When this voltage is removed, the rotator stops. The position of the rotator is indicated by varying voltage on a different line that is sampled by the A/D converter.

AUTOMATION

Two different options existed for developing an automation program for the system. Either a controller program similar to other existing programs could be used or an entirely new type of program could be written. The first option was chosen in the interest of minimizing the training of operators for use of a different type of system. A controller program named LOWGO was written for the HP 9845B instrument controller to automate the system. This program initially asks the operator a series of questions that describe the type of evaluation needed, computes the necessary frequencies and voltages for the equipment, and establishes the magnetic field desired. At this point, the program will either pause for manual evaluations, make automatic evaluations on instruments under test having a recorder output, or read the spectrum analyzer when antennas or other appropriate equipment are being tested. It then computes the error from the established field and displays the results in graphs and tables. Manual evaluations are necessary when the instrument being tested does not have a recorder output and the operator must read the meter directly. The program merely sets the desired field in this case and no printouts are generated.

The controller program was created by custom fitting various library routines to the particular needs of the system and writing the necessary calculation routines to fit into the customized program. Special routines had to be written to control the signal generator, spectrum analyzer, and digital multimeter as these particular instruments are not used in other similar programs. Another routine was written to display and printout the information from the spectrum analyzer. The final result is a controller program which is one of a set of programs which are continually being revised and improved

within the Branch to make the controller series programs faster, easier to use, and more accurate. These programs are very user friendly, requiring very little work by the operator.

When the program is initially started, it checks to see if all revelant equipment is on and in the proper operating mode. If this is not the case, the operator is notified via a message displayed on the screen and the program begins recursive operations until all equipment is set up correctly. This is done in lines 1020 to 1810 for the printer, rotator and relay actuator, signal generator, digital multimeter, and spectrum analyzer.

Beginning in line 1820 and extending to line 2620, questions are asked concerning the evaluation procedure to be used and the desired field, such as the operator's name, the title of the evaluation, whether the evaluation is manual, automatic, or uses the spectrum analyzer, what units of measurement does the instrument being tested use, what frequencies and field strength are desired, whether or not the observation will be made based on time or rotation, and what are the characteristics of the metering instrument.

The field is established in line 2630 to 3110 by transmitting commands to the signal generator and reading the digital multimeter as feedback to check for proper values. If the initial reading on the multimeter indicates that the field is not correct, a binary search adjusts the output of the signal generator until programmed tolerances are met. At this point, the program checks to see if manual evaluations were requested and pauses if that condition is true. The operator presses the CONTinue button of the HP 9845B to set the desired field at a new frequency and this process is repeated until the evaluation is complete.

If either automatic or spectrum analyzer operations are selected, the program receives data from the proper equipment in lines 3120 to 3960. For automatic operation, data is received from the A/D converter in lines 3350 to 3650. The spectrum analyzer is sampled in lines 3690 to 3870. After the sampling is complete, the program checks to see what changes occurred in the magnetic field during the sampling by reading the digital multimeter in lines 3880 to 3960.

The data received from the A/D converter is converted to suitable values for plotting in lines 3970 to 4300 and displayed on the screen in lines 4310 to 6390, dumping to the printer when the screen is filled. After all desired frequencies have been evaluated, summary tables and plots computed in lines 6400 to 6800 are printed. The data from the evaluation can be saved permanently if desired on disk or tape in lines 6810 to 7260.

OPERATING THE SYSTEM

Using this system is relatively easy and does not require much equipment. As can be seen in these instructions, the operator does not have very much to do to obtain accurate evaluations of instruments. These instructions provide all the necessary steps to complete an evaluation using the low frequency magnetic field calibration system.

1. Place an HP-IB (Hewlett-Packard Interface Bus) extender in the equipment rack containing the system components next to the HP 3314A signal generator and connect HP-IB cables from the extender to the signal generator, from the signal generator to the HP 3490A digital multimeter, and from the digital multimeter to the HP 3582A spectrum analyzer.

2. Attach a suitably long cable with BNC connections on each end between the extender located with the system components and an extender located near the 9845B computer.

3. Connect this second extender to HP-IB Select Code 7 and make sure that the printer, A/D converter, and relay actuator are connected to HP-IB Select Code 10.

4. Turn on power to all equipment and adjust the output attenuator on the Crown M600 amplifier so that it is about three quarters of the way toward maximum. The system is now ready for operation.

5. Load the controller program LOWGO from the hard disk by typing 'LOAD "LOWGO:X"' on the 9845B computer and pressing EXECute.

6. Press RUN. The program will initially check to see that all equipment is on and in the proper operating mode and then ask for the operator's name.

7. Enter the operator's name and press CONTinue.

8. Enter the title of the measurement and press CONTinue.

9. Select the type of evaluation desired and answer all of the questions from the program.

10. If manual evaluations are selected, the program will establish the desired field and pause. When all desired measurements have been taken, the operator should press CONTinue to establish the desired field at the next frequency.

11. If automatic evaluations are selected, the operator does not have anything else to do until the program is finished sampling data. The program will set the fields and receive data from the desired instrument, repeating the process at all desired frequencies. All necessary calculations are performed in the program and the results are printed in graphical form for each frequency.

12. When the automatic sampling is finished the program asks for comments. Here the operator should note any observation or special conditions which may have revelance to the evaluation. The program will then print summary tables and graphs and ask for the next set of frequencies.

13. If no other evaluations are desired, the program can be stopped at this time. For evaluations at different field strengths, the program should be restarted by pressing RUN and repeating the procedure from step 7.

REMAINING WORK

A few details need to be accomplished to complete the low frequency magnetic field calibration system. Once the 0.1 ohm current shunt is purchased, a complete study must be performed to determine its impedance at all frequencies and power levels that may be used in the system. This is necessary because this resistor will the standard on which currents are measured in the Helmholtz coil and therefore the basis for the generation of accurately known magnetic fields. Additionally, a study should be made of the fields generated by this system to determine the variation in the fields over a period of several hours. Lastly, a program needs to be written to compute antenna factors in decibels with respect to milligauss as this is the unit used in the automation program used in this system.

To complete a general low frequency calibration system, an electric field generation system needs to be built. This electric field system will complement the magnetic field system designed in this project and will allow complete characterization of antennas and field strength measurement instruments at low frequencies. The automation program should then be extended to allow either electric or magnetic field evaluations to be made. Some of the necessary revisions have already been incorporated in the LOWGO automation program in anticipation of this phase of the project.

CONCLUSIONS

The low frequency magnetic field calibration system has been designed, fabricated, and implemented for generating magnetic fields from 0.5 to 1000 mG over a frequency range of 0 to 20 kHz. The computer program that controls the system is flexible in that it allows the user to perform manual or automatic evaluations with the results of automatic evaluations being printed out in suitable format for documentation purposes. Additionally, this system is flexible enough to incorporate future modifications that will be necessary when an electric field calibration system is established.

This project is the beginning of an expansion by the Nonionizing Radiation Branch into further studies of the low frequency area. This study has particular relevance in that current power line frequency is 60 Hz and there are recent developments in establishing high voltage DC power transmission lines. Once research is completed establishing safe levels of exposure in these areas, this project will allow instruments used to measure the exposure to be evaluated quickly and accurately.

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APPENDIX A: PROGRAM LISTINGS

Program	Description
LOWGO	The controller program for the Low Frequency Magnetic Field Calibration System
FIELDS	Program to compute the magnetic field in and around a Helmholtz coil
INTERP	Program to smooth out the data generated by FIELDS

```
10    ! ********************************************************************************
20    ! *                                                                              *
30    ! *  PROGRAM NAME: LOWGO                          REVISION: A  11/14/83          *
40    ! *                                                                              *
50    ! *  COMPUTER: HP 9845B                                                          *
60    ! *                                                                              *
70    ! *  PROGRAMMERS:  Arthur P. Ludwigsen and Micheal R. Molony                     *
80    ! *                Non-Ionizing Radiation Branch                                 *
90    ! *                                                                              *
100   ! *  DESCRIPTION:                                                                *
110   ! *     This program will direct equipment to generate accurately known          *
120   ! *     electric and magnetic field intensities for the purpose of               *
130   ! *     evaluating the response of broadband, low frequency measurement          *
140   ! *     devices.  This system provides a convenient and accurate method          *
150   ! *     to evaluate measurement device response to low frequency                 *
160   ! *     electric and magnetic fields and therefore establish uncertainty         *
170   ! *     limits for instrument readings obtained in hazard survey                 *
180   ! *     measurements.                                                            *
190   ! *                                                                              *
200   ! *  WARRANTY:                                                                   *
210   ! *     The Non-Ionizing Radiation Branch of EPA warrants only that              *
220   ! *     testing has been applied to this code. No other warranty                 *
230   ! *     expressed or implied, is applicable.                                     *
240   ! *                                                                              *
250   ! ********************************************************************************
260   !
270   !
280   !
290   !
300   ! 0.0     HPIB DEVICE ADDRESSES      Select Code #10      09/27/83
310   !
320   ! Model #   Description                                  Address Code
330   !
340   ! 2631G     HP-IB Graphics Character Printer                  01
350   ! 59313A    Analog to Digital Converter                       06
360   ! 59306A    Relay Actuator                                    16
370   !
380   ! 0.1     HPIB DEVICE ADDRESSES      Select Code #7       10/25/83
390   !
400   ! Model #   Description                                  Address Code
410   !
420   ! 3314A     Function Generator                                07
430   ! 3490A     Digital Multimeter                                22
440   ! 3582A     Real-Time Spectrum Analyzer                       11
450   !
460   ! 1.0   C O M M O N,  D A T A  T Y P E  D E F I N I T I O N S  A N D
470   !
480   !                P R O G R A M  I N I T I A L I Z A T I O N
490   !
500   !
510   ! 1.1                  S T O R A G E  A L L O C A T I O N
520   !
530   COM INTEGER Generator,Dmm
540   COM Title$[80],Oper$[80]
550   SHORT Plotdb(900),Freqz(200),Pre_err(200),Post_err(200),Avgi(200)
560   SHORT Errdbi(200),Pmini(200),Pmaxi(200),Status,Valx,Xi,Yi
570   SHORT Max_freqz,Min_freqz
580   INTEGER I,Year,B(900),Dir(900),Xorg(3),Yorg(3),Slen,Samp_size,Sel,Equip
590   INTEGER Card1,Card2,Clock,Printer,Analyzer,A_d_conv,Rotator,Nf
```

```
600   INTEGER Px1(1,3),Px2(2,3),Py1(1,3),Py2(3,3)
610   DIM Units$(1:6,1)[25],C$(10)[160],System$(1)[15],A(255),M$[130]
620   !
630   ! 1.2          A S S I G N M E N T   O F   V A R I A B L E S
640   !
650   READ Xorg(*),Yorg(*)
660   DATA 2.5,12.5,2.5,12.5,  10,10,3,3
670   READ Px1(*),Py1(*)
680   DATA 15,75,15,75,  50,110,50,110,  55,55,10,10,  85,85,40,40
690   READ Px2(*),Py2(*)
700   DATA 0,65,0,65, 61,126,61,126, 60,125,60,125, 45,45,0,0, 90,90,44,44, 49.5
,49.5,4.5,4.5, 84,84,38,38
710   !
720   Esc$=CHR$(27)        ! ** ASCII code 27 used for escape sequences
730   Quote$=CHR$(34)
740   !
750   Units$(1,0)="kV/m"
760   Units$(1,1)="A/m"
770   Units$(2,0)="V/m"
780   Units$(2,1)="mGauss"
790   Units$(3,0)="V/cm"
800   Units$(3,1)="F"
810   Units$(4,0)="dBuV/m"
820   Units$(4,1)="dBuA/m"
830   Units$(5,0)="V"
840   Units$(5,1)="mG"
850   !
860   System$(0)="Parallel Plates"
870   System$(1)="Helmholtz Coil"
880   !
890   Slen=700             ! ** Initial value for sample length **
900   Store$=":X12,0,0"    ! ** Default Mass Storage Device **
910   Version$="A  11/14/83."
920   !
930   Card1=10             ! ** HP-IB 98034A Select Code **
940   Card2=7              ! ** HP-IB 98034A Select Code **
950   Clock=9              ! ** HP 98035A Real Time Clock **
960   Generator=Card2*100+7     ! ** Address of Signal Generator **
970   Analyzer=Card2*100+11     ! ** Address of Spectrum Analyzer **
980   Dmm=Card2*100+22          ! ** Address of Digital Multimeter **
990   Printer=Card1*100+1       ! ** Address of Printer **
1000  A_d_conv=Card1*100+6      ! ** Address of A/D Converter **
1010  Rotator=Card1*100+16      ! ** Address of Relay Actuator **
1020  !
1030  ! 1.3        S E T   D E F A U L T S   F O R   E X E C U T I O N
1040  !
1050  MASS STORAGE IS Store$
1060  EXIT GRAPHICS
1070  SERIAL
1080  PRINTER IS 16
1090  ON ERROR GOSUB Err20
1100  ON KEY #8 GOSUB Setup_screen
1110  !
1120  ! 2.0              P R O G R A M   I N T R O D U C T I O N
1130  !
1140  CALL Time(Date$,Time$,Day$,Month$,Year,2)
1150  PRINT Esc$&"E";"PROGRAM: LOWGO                Version: ";Version$;LIN(1)
1160  PRINT "   Mass Storage defaults to: ";Quote$&Store$&Quote$
1170  PRINT "   HP Real Time Clock Select Code: ";Clock
1180  PRINT "   HP-IB Select Codes are: ";Card2;"and";Card1
```

```
1190  PRINT "    HP-IB Generator is on Address: ";TAB(43);Generator
1200  PRINT "    HP-IB Spectrum Analyzer is on Address: ";TAB(43);Analyzer
1210  PRINT "    HP-IB Multimeter is on Address: ";TAB(43);Dmm
1220  PRINT "    HP-IB Printer is on Address: ";TAB(42);Printer
1230  PRINT "    HP-IB A/D converter is on Address: ";TAB(42);A_d_conv
1240  PRINT "    HP-IB Actuator is on Address: ";TAB(42);Rotator;LIN(1)
1250  PRINT "A/D Calibration Settings"
1260  PRINT "    Channel #1: 1 V";TAB(25);"Meter Recorder Output"
1270  PRINT "    Channel #2: 3.5 V";TAB(25);"Meter Recorder Output"
1280  PRINT "    Channel #3: 3.5 V";TAB(25);"Rotator Reading";LIN(1)
1290  !
1300  ! 2.1        C H E C K   S T A T U S   O F   D E V I C E S
1310  !
1320  ! 2.11  2631G Line Printer
1330  !
1340  SET TIMEOUT Card1;1
1350  ON INT #Card1 GOTO 1420
1360  STATUS Printer;Cond
1370  OUTPUT Printer USING "#,K";Esc$&"n"              !turn printer on-line
1380  STATUS Printer;Cond
1390  IF BIT(Cond,6) THEN 1440              !hard off-line, user must turn on-line
1400     DISP "TURN PRINTER ON-LINE."
1410     GOTO 1380
1420  DISP "NO POWER APPLIED TO 2631G PRINTER"
1430  GOTO 1360
1440  OFF INT #Card1
1450  SET TIMEOUT Card1;10000
1460  !
1470  ! 2.12  Probe Rotator and A/D converter
1480  !
1490  OUTPUT A_d_conv;"H4AJ"
1500  N=SHIFT(READBIN(A_d_conv),-8)+READBIN(A_d_conv,6)
1510  IF ABS(N)<>0 THEN 1570
1520     DISP "NO POWER APPLIED TO ROTATOR, OR OUT OF CALIBRATION."
1530     GOTO 1490
1540  !
1550  ! 2.13  Function Generator
1560  !
1570  SET TIMEOUT Card2;1
1580  ON INT #Card2 GOTO 1610
1590  STATUS Generator;Cond
1600  GOTO 1660
1610     DISP "Turn on h-p 3314A Function Generator"
1620     GOTO 1570
1630  !
1640  ! 2.14  Digital Multimeter
1650  !
1660  SET TIMEOUT Card2;1000
1670  ON INT #Card2 GOTO 1710
1680  OUTPUT Dmm;"R7F2T1M1E"                !set multimeter to default state
1690  ENTER Dmm;A$
1700  GOTO 1760
1710     DISP "Turn on h-p 3490A Digital Multimeter"
1720     GOTO 1690
1730  !
1740  ! 2.15  Spectrum Analyzer
1750  !
1760  SET TIMEOUT Card2;1
1770  ON INT #Card2 GOTO 1800
1780  STATUS Analyzer;Cond
```

```
1790  GOTO 1850
1800     DISP "Turn on h-p 3582A Spectrum Analyzer"
1810     GOTO 1760
1820  !
1830  ! 2.2     D E F I N E   M E A S U R E M E N T   P A R A M E T E R S
1840  !
1850  OFF INT #Card2
1860  SET TIMEOUT Card2;10000
1870  OUTPUT Dmm;"R7F2T1M1E"                    !set multimeter to default state
1880  OUTPUT Rotator;"A4B56"                    !set actuator switches to default state
1890  !
1900  ! 2.21  Identify the Measurement
1910  !
1920  EDIT "Enter operator identification",Oper$
1930  EDIT "Enter a title for this measurement",Title$
1940  DISP "Is data collection (1) manual, (2) A/D converter, or (3) Spectrum An
alyzer";
1950  INPUT Equip
1960  IF (Equip=1) OR (Equip=2) OR (Equip=3) THEN 1990
1970     CALL Dcol("Only selections 1, 2, or 3 are allowed, try again.")
1980     GOTO 1940
1990  GOSUB Get_freq                            !enter frequencies into array Freq(*)
2000  IF Equip<>2 THEN 2100
2010     Rot$="Y"
2020     INPUT "Do you need rotation? (Y or N)",Rot$
2030     IF Rot$="Y" THEN 2100
2040        INPUT "Enter measurement time span in seconds",Delay
2050  !
2060  ! 2.3     D E F I N E   T H E   F I E L D   T O   E S T A B L I S H
2070  !
2080  ! 2.31  Select Electric or Magnetic
2090  !
2100  Sel=1
2110  INPUT "Do you want to enter Electric(0) or Magnetic(1) field units?",Sel
2120  IF (Sel=0) OR (Sel=1) THEN 2180
2130     CALL Dcol("Only selections 0 or 1 are allowed, try again.")
2140     GOTO 2100
2150  !
2160  ! 2.32  Select the Units to use
2170  !
2180  N=2
2190  IF Sel=0 THEN DISP "Enter units: (1) kV/m, (2) V/m, (3) V/cm, or (4) dBu
V/m";
2200  IF Sel=1 THEN DISP "Enter units: (1) A/m, (2) mGauss, (3) T, or (4) dBuA
/m";
2210  INPUT N
2220  IF (N<1) OR (N>6) THEN 2190
2230  !
2240  ! 2.33  Enter the Field and Convert to mGauss (magnetic) or V/m (electric)
2250  !
2260  DISP "Enter Desired Field in "&Units$(N,Sel);
2270  INPUT Valx
2280  IF (N<>4) AND ((Valx<0) OR (Valx>1.0E8)) THEN 2190
2290  IF (N=4) AND (Valx>250) THEN 2190
2300  Inval=Valx
2310  !
2320  IF N=4 THEN Valx=10^(Valx/20-6)
2330  IF ((N=1) OR (N=4)) AND (Sel=1) THEN Valx=Valx*4*PI
2340  IF (N=1) AND (Sel=0) THEN Valx=Valx*1000
2350  IF (N=3) AND (Sel=0) THEN Valx=Valx*100
```

```
2360  IF (N=3) AND (Sel=1) THEN Valx=Valx*1E7
2370  IF Sel=1 THEN I_init=Valx*5^1.5/(192*PI)
2380  V_init=.001*I_init
2390  Setdb=20*LGT(Valx)
2400  IF Equip()2 THEN Start
2410  !
2420  ! 2.34  Enter Meter Parameters
2430  !
2440  INPUT "Enter Meter Full Scale Voltage",Fsvolts
2450  IF Fsvolts)5 THEN 2440
2460  DISP "Enter Meter Full Scale Field in "&Units$(N,Sel);
2470  INPUT Fsval
2480  IF N=4 THEN INPUT "Enter scale range in dB",Fsrange
2490  !
2500  ! 2.35  Computer Selects the proper A/D Channel
2510  !
2520  Cn=2
2530  Cnset=3.5 !Volts
2540  IF ABS(Fsvolts))1 THEN 2570
2550     Cn=1
2560     Cnset=1 !Volt
2570  Conv=Cnset/1022
2580  Instr$="H"&VAL$(2^(Cn-1))&"AJ"      !command to sample channel 'Cn'
2590  PRINT LIN(1);"CAUTION"
2600  PRINT "   1. Check Hardware before CONTinuing"
2610  DISP "Connect meter recorder output to Ch# ";VAL$(Cn);". Press CONTinue wh
en ready."
2620  PAUSE
2630  !
2640  ! 3.0                    P R O G R A M   E X E C U T I O N
2650  !
2660  ! 3.1  I N I T I A L I Z E   E Q U I P M E N T   F O R   E X E C U T I O N
2670  !
2680  ! 3.11A  Position Probe
2690  !
2700  IF Rot$="N" THEN 2800
2710     Mdir=1
2720     OUTPUT A_d_conv;"H4AJ"
2730     Dig=SHIFT(READBIN(A_d_conv),-8)+READBIN(A_d_conv)
2740     IF Dig(15 THEN Start
2750        DISP "Positioning Probe."
2760        GOTO 2720
2770  !
2780  ! 3.11B  Set Timer
2790  !
2800  Slen=1E6
2810  OUTPUT Clock;"All units halt. Uniti is set = to Output1"
2820  OUTPUT Clock;"U1D"&VAL$(Delay*1000)
2830  ON INT #Clock GOTO 3610
2840  !
2850  ! 3.12  Setup LOWGO Screen
2860  !
2870 Start: DISP
2880  Gp=0
2890  GOSUB Setup_screen
2900  !
2910  FOR I=0 TO Nf
2920  Try=1
2930  Cf=Freqz(I)
2940  F=FNC(Cf*1000,F$,2)
```

```
2950  !
2960  ! 3.13  Update Screen with Current Measurement Parameters
2970  !
2980  SWRITE 7,16,VAL$(F)&" "&F$&"    "
2990  SWRITE 8,26,VAL$(PROUND(Setdb,-2))&" dB"&Units$(S,Sel)
3000  SWRITE 9,25,VAL$(PROUND(V_init*1000,-2))&" mV"
3010  SWRITE 10,27,"              "
3020  SWRITE 11,25,"              "
3030  SWRITE 14,1,RPT$(" ",55)
3040  !
3050  ! 3.14  Program Frequency and Amplitude on Generator
3060  !
3070  CALL Set_freq_3314(Cf)
3080  CALL Set_amp_3314(I_init)
3090  GOSUB Adjust_amp
3100  Pre_err(I)=PROUND((V2-V_init)*1000,-2)
3110  DISP
3120  !
3130  !
3140  ! 3.2                    S A M P L E   R E S P O N S E
3150  !
3160  Try=Try+1
3170  SWRITE 10,28,VAL$(Pre_err(I))&" mV"
3180  SWRITE 14,1,"Field Established in "&System$(Sel)&": "&VAL$(Inval)&" "&Unit
s$(N,Sel)
3190  IF Equip()1 THEN 3240
3200     DISP "Press CONTinue for the next frequency"
3210     PAUSE
3220     NEXT I
3230     END
3240  IF Equip()3 THEN 3280
3250     DISP "Set Analyzer to desired configuration and press CONTinue"
3260     LOCAL Analyzer
3270     PAUSE
3280  DISP "      Sampling data."
3290  IF Equip=3 THEN 3690
3300  REDIM Dir(Slen),B(Slen),Plotdb(Slen)
3310  MAT Dir=ZER
3320  MAT B=ZER
3330  SUSPEND INTERACTIVE
3340  IF Rot$="N" THEN 3570
3350  !
3360  ! 3.21A  Sample Data from Instrument and Rotator Box
3370  !
3380     IF Mdir)0 THEN OUTPUT Rotator;"B4A6"       !probe clockwise
3390     IF Mdir(0 THEN OUTPUT Rotator;"B6A4"       !probe counter-clockwise
3400     FOR J=0 TO Slen
3410        OUTPUT A_d_conv;Instr$      !A/D Channel for Probe
3420        ENTER A_d_conv BFHS 2 NOFORMAT;B(J)
3430        OUTPUT A_d_conv;"H4AJ"      !A/D Channel for Rotator Position
3440        ENTER A_d_conv BFHS 2 NOFORMAT;Dir(J)
3450     NEXT J
3460     RESUME INTERACTIVE
3470     FOR J=Slen-1 TO 400 STEP -1
3480        IF ABS(Dir(J)-Dir(J+1)))5 THEN 3620
3490        IF B(J)(=0 THEN Err21
3500     NEXT J
3510 Err19:  DISP "System Malfunction  Check rotator connections."
3520  PAUSE
3530  GOTO 2980
```

```
3540  !
3550  !  3.21B  Sample data from instrument while in delay
3560  !
3570  OUTPUT Clock;"UIG"
3580  FOR J=0 TO Slen
3590     ENTER A_d_conv;Instr$
3600  NEXT J
3610  RESUME INTERACTIVE
3620  IF J<Slen-2 THEN 3710
3630 Err18:  DISP "Program Malfunction  Sample size larger than";Slen
3640  PAUSE
3650  GOTO 2980
3660  !
3670  ! 3.21C  Sample Data from Spectrum Analyzer
3680  !
3690  OUTPUT Analyzer;"LSP"
3700  ENTER Analyzer;Span
3710  Marker=INT(256*Cf/Span)-1
3720  OUTPUT Analyzer;"IM3MN1MP"&VAL$(Marker)
3730  OUTPUT Analyzer;"LMK"
3740  ENTER Analyzer;Temp,Freq
3750  IF ABS(Cf-Freq)<=Cf/Span THEN 3790
3760     Marker=Marker+SGN(Cf-Freq)
3770     OUTPUT Analyzer;"MP"&VAL$(Marker)
3780     GOTO 3730
3790  OUTPUT Analyzer;"AA0AB1AX0NU3AV2"
3800  OUTPUT Analyzer;"LST1"
3810  IF NOT BIT(READBIN(Analyzer),6) THEN 3800
3820  OUTPUT Analyzer;"LMK"
3830  ENTER Analyzer;Amax,Freq
3840  OUTPUT Analyzer;"LAN"
3850  ENTER Analyzer;M$
3860  OUTPUT Analyzer;"LDS"
3870  ENTER Analyzer;A(*)
3880  !
3890  ! 3.22  Check for drift
3900  !
3910  CALL Read_3490(V_final)
3920  Post_err(I)=PROUND((V_init-V_final)*1000,-2)
3930  SWRITE 11,26,VAL$(Post_err(I))&" mV"
3940  Power=0
3950  Slen=J*1.15
3960  Samp_size=J
3970  !
3980  ! 3.23  Convert Values to Plotting Units and sum up powers
3990  !
4000  IF Equip=3 THEN 4210
4010  REDIM Dir(Samp_size),B(Samp_size),Plotdb(Samp_size)
4020  DISP "     Converting values for plotting. (Sample =";Samp_size;")"
4030  IF Rot$="N" THEN Mdir=-1
4040  IF N<>4 THEN 3950
4050     FOR J=0 TO Samp_size
4060        Tmp=Fsval-Fsrange+B(J)*Conv/Fsvolts*Fsrange
4070        IF Mdir=-1 THEN Plotdb(J)=Tmp-Setdb
4080        IF Mdir=1 THEN Plotdb(Samp_size-J)=Tmp-Setdb
4090        Power=Power+10^(Tmp/20)^2
4100     NEXT J
4110     GOTO 4220
4120  FOR J=0 TO Samp_size
4130     Tmp=B(J)*Conv/Fsvolts*Fsval
```

```
4140     IF Mdir=-1 THEN Plotdb(J)=20*LGT(Tmp)-Setdb
4150     IF Mdir=1 THEN Plotdb(Samp_size-J)=20*LGT(Tmp)-Setdb
4160     Power=Power+Tmp*Tmp
4170  NEXT J
4180  !
4190  ! 3.24  Compute Average
4200  !
4210  IF Equip=3 THEN 4290
4220     Avgi(I)=Power/Samp_size
4230     Errdbi(I)=20*LGT(Avgi(I))-Setdb
4240     IF ((N=1) OR (N=4)) AND (Sel=0) THEN Avgi(I)=Avgi(I)/12.5
4250     IF (N=1) AND (Sel=0) THEN Avgi(I)=Avgi(I)/1000
4260     IF (N=3) AND (Sel=0) THEN Avgi(I)=Avgi(I)/100
4270     IF (N=3) AND (Sel=1) THEN Avgi(I)=Avgi(I)/1E7
4280     IF N=4 THEN Avgi(I)=20*LGT(Avgi(I))
4290     GOTO 4340
4300  Errdbi(I)=Set_db-20-Amax
4310  !
4320  ! 4.0              G R A P H I C S   A N D   T A B L E S
4330  !
4340  MAT SEARCH Plotdb(*),MIN;Pmini(I)
4350  MAT SEARCH Plotdb(*),MAX;Pmaxi(I)
4360  OVERLAP
4370  DISP
4380  GRAPHICS
4390  IF Gp>0 THEN 4650
4400  !
4410  ! 4.1              I N I T I A L I Z E   G R A P H I C S
4420  !
4430  ! 4.11  Plotting Titles
4440  !
4450     PLOTTER IS "GRAPHICS"
4460     SCALE 0,15,0,15
4470     DEG
4480     LORG 5
4490     CSIZE 5,7/15
4500     MOVE 7.5,14.7
4510     LABEL USING "#,K";Title$
4520     CSIZE 3.5,8/15
4530     MOVE 3,13.9
4540     IF Equip=3 THEN MOVE 7.5,13.9
4550     LABEL USING "#,K";"Applied Field: "&VAL$(Inval)&" "&Units$(N,Sel)
4560     MOVE 12,13.9
4570     IF Equip=3 THEN 4630
4580     LABEL USING "#,K";"Meter Full Scale: "&VAL$(Fsval)&" "&Units$(N,Sel)
4590     IF I>0 THEN 4650
4600  !
4610  ! 4.12  Program Printer for Perforation Skip, and Dump Title
4620  !
4630  OUTPUT Printer USING "#,K";CHR$(12)&CHR$(10)&Esc$&"&l66p58f6d1L"
4640  DUMP GRAPHICS #Card1;13.5,15
4650  IF Equip=3 THEN 5950
4660  !
4670  ! 4.13  Setup Scales for Polar and Rectangular Plots
4680  !
4690  Dbmin=PROUND(Pmini(I)-.5,0)       !round to nearest dB
4700  Dbmax=PROUND(Pmaxi(I)+.5,0)
4710  IF Rot$="N" THEN 5520
4720  !
4730  ! 4.20              P O L A R   P L O T S
```

```
4740  !
4750  ! 4.21  Setup Plotting Parameters for Polar Plots on Rotation
4760  !
4770     SHOW 0,15,0,15
4780     IF I=8 THEN OUTPUT Printer USING "#,K";Esc$&"&l66p54f6d1L"
4790     Xorg=Xorg(Gp)
4800     Yorg=Yorg(Gp)
4810     Rmin=.5
4820     Rmax=2.5
4830     Rtic=2
4840     CSIZE 2.25,7/15
4850  !
4860  ! 4.22  Draw Plotting Area
4870  !
4880     MOVE Xorg,Rmax*1.3+Yorg
4890     LABEL USING "#,K";VAL$(Cf)&" kHz"
4900     LDIR 90
4910     MOVE COS(180)*Rmax*1.5+Xorg,Yorg
4920     LABEL USING "#,K";"dB Error"
4930     LORG 5
4940     LDIR 0
4950     MOVE Xorg,Yorg
4960     LABEL USING "#,1X,K";Dbmin
4970     MOVE Rmax*1.1+Xorg,Yorg
4980     LABEL USING "#,K";Dbmax
4990     FOR R=Rmin TO Rmax STEP Rtic
5000        FOR A=0 TO 360 STEP 4
5010           PLOT COS(A)*R+Xorg,SIN(A)*R+Yorg
5020        NEXT A
5030        PENUP
5040     NEXT R
5050     FOR A=0 TO 300 STEP 60
5060        Angle=A+90
5070        X1=COS(Angle)*Rmax
5080        Y1=SIN(Angle)*Rmax
5090        MOVE COS(Angle)*Rmin+Xorg,SIN(Angle)*Rmin+Yorg
5100        DRAW X1*1.05+Xorg,Y1*1.05+Yorg
5110        MOVE X1*1.2+Xorg,Y1*1.2+Yorg
5120        IF (A=0) OR (A=180) THEN MOVE X1*1.15+Xorg,Y1*1.15+Yorg
5130        LABEL USING "#,K";(360-A) MOD 360;CHR$(179)
5140     NEXT A
5150  !
5160  ! 4.23  Plot converted data
5170  !
5180     M=(Rmax-Rmin)/(Dbmax-Dbmin)
5190     C1=Rmin-M*Dbmin
5200     IF ABS(Dbmax-Dbmin)<2 THEN 5280
5210        LDIR -30
5220        FOR Tic=Dbmin+1 TO Dbmax-1
5230           R=M*Tic+C1
5240           MOVE R*COS(-30)+Xorg,R*SIN(-30)+Yorg
5250           LABEL USING "#,K";"|"
5260        NEXT Tic
5270        LDIR 0
5280     F7=360/Samp_size          !Compute a scaling factor
5290     FOR J=0 TO Samp_size
5300        Angle=J*F7-90
5310        R=M*Plotdb(J)+C1
5320        X=R*COS(Angle)+Xorg
5330        Y=R*SIN(Angle)+Yorg
```

```
5340        PLOT X,Y
5350     NEXT J
5360  !
5370     PENUP
5380     R=M*Errdbi(I)+C1
5390     FOR J=0 TO 360 STEP 4
5400        X=R*COS(J)+Xorg
5410        Y=R*SIN(J)+Yorg
5420        PLOT X,Y
5430     NEXT J
5440  !
5450     SERIAL
5460     GOTO 6300
5470  !
5480  !  4.3      R E C T A N G U L A R   P L O T S
5490  !
5500  !  4.31  Setup Plotting Parameters for Rectangular Plots on Delay
5510  !
5520  LOCATE Px1(0,Gp),Px1(1,Gp),Py1(0,Gp),Py1(1,Gp)
5530  SCALE 0,Samp_size,Dbmin,Dbmax
5540  FRAME
5550  CSIZE 2.25,7/15
5560  X_corr=Samp_size*.13
5570  Y_corr=ABS((Dbmax-Dbmin)/2)
5580  Grid_x=Delay/5
5590  Grid_y=Dbmax-Dbmin-1
5600  AXES Grid_x,Grid_y,0,Dbmin
5610  LORG 8
5620  FOR L=Dbmin TO Dbmax
5630     MOVE 0,L
5640     LABEL USING "#,MDZ,X";L
5650  NEXT L
5660  LORG 6
5670  FOR L=0 TO Delay
5680     MOVE L,-Y_corr
5690     LABEL USING "#,DDD,X";L
5700  NEXT L
5710  MOVE 0,Errdbi(I)
5720  DRAW Samp_size,Errdbi(I)
5730  MOVE 0,Dbmin
5740  !
5750  ! 4.32  Plot Converted Data
5760  !
5770  FOR J=0 TO Samp_size
5780      PLOT J,Plotdb(J)
5790  NEXT J
5800  !
5810  ! 4.33  Plot Labels
5820  !
5830  LDIR 90
5840  LORG 5
5850  MOVE -X_corr,(Dbmin+Dbmax)/2
5860  LABEL USING "#,K";"dB Error"
5870  LDIR 0
5880  MOVE Samp_size/2,-2*Y_corr
5890  LABEL USING "#,K";"Time (s)"
5900  GOTO 6300
5910  !
5920  !  4.4   S P E C T R U M   A N A L Y Z E R   D I S P L A Y
5930  !
```

```
5940  !  4.41  Get parameters from Analyzer
5950  !
5960  IF I=8 THEN OUTPUT Printer USING "#,K";Esc$&"&l66p54f6d1L"
5970  OUTPUT Analyzer;"LBS"
5980  ENTER Analyzer;Dbmax
5990  !
6000  !  4.42  Calculate position and spacing and plot labels
6010  !
6020  Dbmin=Dbmax-8*10 !10 dB/div
6030  Xtic=Span/5000
6040  LOCATE Px2(0,Gp),Px2(1,Gp),Py2(0,Gp),Py2(1,Gp)
6050  SCALE 0,100,0,100
6060  CSIZE 2.6,5/7
6070  LORG 1
6080  MOVE 0,95
6090  LABEL USING "#,K";M$[1,32]
6100  MOVE 0,90
6110  LABEL USING "#,K";M$[33,64]
6120  MOVE 0,5
6130  LABEL USING "#,K";M$[65,96]
6140  MOVE 0,0
6150  LABEL USING "#,K";M$[97,128]
6160  !
6170  ! 4.43  Plot display
6180  !
6190  LOCATE Px2(0,Gp),Px2(2,Gp),Py2(2,Gp),Py2(3,Gp)
6200  SCALE 0,255,Dbmin,Dbmax
6210  FRAME
6220  AXES Xtic,10,0,Dbmin
6230  MOVE 0,Dbmin
6240  FOR J=0 TO 255
6250     PLOT J,A(J)
6260  NEXT J
6270  !
6280  ! 4.5     D U M P   G R A P H I C S
6290  !
6300  Gp=Gp+1
6310  IF Gp<4 THEN 6350
6320     DUMP GRAPHICS #Card1;-110,115
6330     OUTPUT Printer;CHR$(10)
6340     Gp=0
6350  EXIT GRAPHICS
6360  NEXT I
6370  GRAPHICS
6380  IF Gp=3 THEN DUMP GRAPHICS #Card1;-110,115
6390  IF Gp<=2 THEN DUMP GRAPHICS #Card1;5,115
6400  !
6410  ! 4.6              P R I N T   R E P O R T   S U M M A R Y
6420  !
6430 Print_report: PRINT PAGE
6440  EXIT GRAPHICS
6450  FOR C=0 TO 10
6460     C$(C)[1,5]="     "
6470     LINPUT "Enter comments and terminate with a blank line.",C$(C)[6]
6480     IF C$(C)="     " THEN 6510
6490     PRINT C$(C)
6500  NEXT C
6510  IF C>0 THEN REDIM C$(C-1)
6520  PRINTER IS Card1,1,WIDTH(80)
6530  PRINT PAGE;LIN(4);TAB((81-LEN(Title$))/2);Title$;LIN(1)
```

```
6540  PRINT Day$;"   ";Month$;" ";Date$[5;2];",";Year;TAB(54);"Start Time:";Time
$;LIN(1)
6550  PRINT "Operator: ";Oper$;TAB(59);System$(Sel);" System"
6560  !
6570  ! 4.61  Statistics
6580  !
6590  PRINT LIN(3);TAB(35);"Statistics";LIN(2)
6600  PRINT " Freq.     Avg. Reading     Avg. Error     Low Error     High Error    H
igh-Low Error"
6610  PRINT " (kHz)       (";Units$(N,Sel)[1,7];")";TAB(30);"(dB)          (dB)
      (dB)          (dB)";LIN(1)
6620  FOR I=0 TO Nf
6630     PRINT USING 6660;Freqz(I);PROUND(Avgi(I),-3);Errdbi(I);Pmini(I);Pmaxi(I
);Pmaxi(I)-Pmini(I)
6640  NEXT I
6650  PRINT LIN(1);"Applied Field = ";PROUND(Inval,-3);Units$(N,Sel)
6660  IMAGE DDD.DDD,4X,SDZ.DDD,5X,MDZ.DD,8X,MDZ.DD,7X,MDZ.DD,10X,MDZ.DD
6670  IF C()0 THEN PRINT LIN(2);"Comments:";LIN(1);C$(*)
6680  !
6690  ! 4.62  Setting Error Summary
6700  !
6710  PRINT PAGE;LIN(1);TAB((55-LEN(Title$))/2);Title$
6720  PRINT LIN(2);TAB(15);"Volt Meter Setting Error";LIN(2)
6730  PRINT "                          Initial            Final"
6740  PRINT "      Frequency     Setting Error     Setting Error"
6750  PRINT "        (kHz)           (mV)              (mV)";LIN(1)
6760  IMAGE 6X,3D.3D,8X,MDZ.DD,12X,MDZ.DD,10X,3D.3D
6770  FOR I=0 TO Nf
6780     PRINT USING 6760;Freqz(I),Pre_err(I),Post_err(I)
6790  NEXT I
6800  CALL Summary_plot(Title$,Nf,Freqz(*),Pmini(*),Pmaxi(*),Errdbi(*))
6810  !
6820 Save_file: !
6830  A$="N"
6840  INPUT "Would you like to SAVE this measurement (YES or NO)?",A$
6850  A$=UPC$(TRIM$(A$[1;1]))
6860  IF A$="N" THEN 7240
6870     IF A$()"Y" THEN Save_file
6880     LINPUT "Enter the File Name to SAVE data on.",File$[1;6]
6890     ASSIGN #1 TO File$,Status
6900     ON ERROR GOTO Errors
6910     IF Status()0 THEN 6990
6920        A$=Null$
6930        DISP "FILE: ";File$&Store$;" already exists. OK to Re-write File (Y
ES or NO)?";
6940        INPUT A$
6950        A$=UPC$(TRIM$(A$[1;1]))
6960        IF A$="N" THEN Save_file
6970        IF A$()"Y" THEN 6920
6980        GOTO Write
6990     IF Status()1 THEN 7030
7000        CREATE File$,15
7010        ASSIGN #1 TO File$
7020        GOTO Write
7030     IF Status()2 THEN Write
7040        DISP "Enter the Protect Code for ";File$;
7050        INPUT Prot$
7060        ASSIGN #1 TO File$,Status,Prot$
7070        GOTO 6910
7080 Write: !
```

```
7090         PRINT #1;Title$,Date$,Time$,Oper$,Sel,N,Inval,Valx,Fsvolts,Fsval
7100         PRINT #1;Fsrange,Version$,C$(*)
7110         FOR I=0 TO Nf
7120            PRINT #1;Freqz(I),Pre_err(I),Post_err(I),Pmini(I),Pmaxi(I),Avgi(I
),Errdbi(I)
7130         NEXT I
7140      ASSIGN #1 TO *
7150      DISP "DATA HAS BEEN STORED SUCCESSFULLY."
7160      WAIT 2000
7170      PRINT LIN(1);"Data has been written to: ";File$&Store$
7180      ON ERROR GOSUB Err20
7190      GOTO 7240
7200 Errors: !
7210      IF ERRN<>59 THEN Err20
7220         PRINT "File ";File$;" is not large enough. "
7230         GOTO Save_file
7240  GOSUB Get_freq
7250  GOTO Start
7260  END
7270  !
7280  ! 5.0              I N - L I N E   S U B R O U T I N E S
7290  !
7300  !
7310 Abort: !                                                          *** Abort
7320  STOP
7330  !
7340 Get_freq: ! Enter Frequencies from the Keyboard                   *** Get Freq
7350  EXIT GRAPHICS
7360  Nf=200    !Maximum Number of Frequencies
7370  REDIM Freqz(Nf),Avgi(Nf),Errdbi(Nf),Pmini(Nf),Pmaxi(Nf),Pre_err(Nf)
7380  REDIM Post_err(Nf)
7390  CALL Enterf(Nf,Freqz(*))
7400  REDIM Freqz(Nf),Avgi(Nf),Errdbi(Nf),Pmini(Nf),Pmaxi(Nf),Pre_err(Nf)
7410  REDIM Post_err(Nf)
7420  MAT SEARCH Freqz(*),MIN;Min_freqz
7430  MAT SEARCH Freqz(*),MAX;Max_freqz
7440  RETURN
7450  !
7460 Setup_screen: ! Setup the LOWGO Screen                            *** Setup_screen
7470  PRINTER IS 16
7480  EXIT GRAPHICS
7490  SCREATE 20,32
7500 Sub_setup: SWRITE 1,19,"Low Frequency Automatic Control System"
7510  SWRITE 4,1,Day$&"    "&Month$&" "&VAL$(VAL(Date$[5;2]))&", "&VAL$(Year)
7520  SWRITE 4,55,"Start Time:"&Time$
7530  SWRITE 6,1,"System Parameters"
7540  SWRITE 6,50,"System: "&System$(Sel)
7550  SWRITE 7,5,"Frequency:"
7560  SWRITE 7,50,"Power:"
7570  SWRITE 8,5,"Set Field Strength:"
7580  SWRITE 9,5,"Calculated Setting:"
7590  SWRITE 9,50,"Amplifier Gain:"
7600  SWRITE 10,5,"Initial Setting Error:"
7610  SWRITE 11,5,"Final Setting Error:"
7620  IF Sel=1 THEN SWRITE 11,50,"Load Impedance"
7630  SWRITE 20,1,"System Status"
7640  RETURN
7650  !
7660 Adjust_amp: ! Adjust amplitude on 3314                            *** Adjust_amp
7670  High=I_init+.5
```

```
7680  Low=I_init-.5
7690  X2=(High+Low)/2
7700  CALL Read_3490(V2)
7710  DISP "     Setting Digital Voltmeter:";PROUND(V2*1000,-2);" mV (Fine)"
7720  I_temp=V2/.001
7730  Temp=I_init-I_temp
7740  IF (ABS(Temp)<=.05) OR (ABS(High-Low)<.01) THEN RETURN
7750     IF I_temp<I_init THEN Low=X2
7760     IF I_temp>I_init THEN High=X2
7770     X2=(High+Low)/2
7780     CALL Set_amp_3314(X2)
7790     GOTO 7700
7800  !
7810  ! Miscellanous Program Errors
7820  !
7830 Err17:  DISP "Program Malfunction  Error in setting frequency on 3314A"
7840  PAUSE
7850  STOP
7860 Err21:  DISP "System Malfunction  Check meter connections."
7870  PAUSE
7880  RETURN
7890 Err20:  DISP "Program Malfunction  Program Error: ";ERRM$
7900  GOTO 7890
7910  !                                                              *** Dcol
7920  SUB Dcol(A$)!
7930  !
7940  ! SUB Dcol(A$)
7950  !     A$     String to Display
7960  !
7970  Size=LEN(A$)
7980  FOR I=0 TO Size-1
7990     DISP TAB(Size-I);A$[1,I+1]
8000     WAIT 50
8010  NEXT I
8020  FOR I=1 TO 3
8030     WAIT 325
8040     DISP A$[2]
8050     WAIT 325
8060     DISP A$
8070     BEEP
8080  NEXT I
8090  WAIT 40*Size
8100  SUBEXIT
8110  SUBEND
8120  !
8130  SUB Time(Date$,Time$,Day$,Month$,INTEGER Year,Type)!          *** Time
8140  !
8150  ! SUB Time(Date$,Time$,Day$,Month$,INTEGER Year,Type)
8160  !     Date$    The current Date in the form " YY/MM/DD."
8170  !     Time$    The current Time in the form " HH.MM.SS." when Type=1
8180  !              or "HH:MM xM" when Type=2
8190  !     Day$     The day of the week
8200  !
8210  DIM Day$(6)[9],Month$(1:12)[9]
8220  INTEGER Month,Day,Hour,Minute,Sec,Weekday,Year_
8230  READ Day$(*),Month$(*)
8240  DATA Saturday,Sunday,Monday,Tuesday,Wednesday,Thursday,Friday
8250  DATA January,February,March,April,May,June,July,August,September
8260  DATA October,November,December
8270  Year=1983
```

```
8280  OUTPUT 9;"Recall time"
8290  ENTER 9;Month,Day,Hour,Minute,Sec
8300  Month$=Month$(Month)
8310  OUTPUT Date$ USING Date_format;Month,Day,Year-1900
8320  IF Type=2 THEN 8350
8330     OUTPUT Time$ USING Time_format1;Hour,Minute,Sec
8340  GOTO 8390
8350     M$="AM"
8360     IF Hour>11 THEN M$="PM"
8370     IF (Hour>12) OR (Hour=0) THEN Hour=ABS(Hour-12)
8380     OUTPUT Time$ USING Time_format2;Hour,Minute,M$
8390  Year_=Year-(Month<3)
8400  Month=Month+12*(Month<3)
8410  Year_=INT(1.25*Year_)-INT(Year_/100)+INT(Year_/400)
8420  Weekday=INT(Day+2.6*(Month+1)+Year_) MOD 7
8430  Day$=Day$(Weekday)
8440  SUBEXIT
8450  !
8460 Date_format:     IMAGE #,1X,ZZ,"/",ZZ,"/",ZZ,"."
8470 Time_format1:    IMAGE #,1X,ZZ,".",ZZ,".",ZZ,"."
8480 Time_format2:    IMAGE #,1X,DD,":",ZZ," ",AA
8490  SUBEND
8500  !                                                                    *** FNC
8510  DEF FNC(V,F$,Pr)!
8520  !
8530  ! DEF FNC(V,F$,Pr)
8540  !     V   Numeric value
8550  !     F$  String equivalent
8560  !     Pr  Power Rounding Factor
8570  !
8580  ! Description
8590  !     Use internally to convert Hz to kHz, Mhz, GHz, etc.
8600  !
8610  DIM Nm$(-1:3)[3]
8620  READ Nm$(*)
8630  DATA mHz,Hz,kHz,MHz,GHz
8640  I=INT(LGT(V)/3)
8650  F$=Nm$(I)
8660  RETURN PROUND(V/10^(I*3),-Pr)
8670  FNEND
                                                          *** Summary Plot
8680  !
8690  SUB Summary_plot(Title$,INTEGER Nf,SHORT Freqz(*),Pmini(*),Pmaxi(*),Ercdbi
(*))
8700  !
8710  INTEGER Point(Nf)
8720  PLOTTER IS "GRAPHICS"
8730  GRAPHICS
8740  DEG
8750  !
8760  ! Setup Scaling, and Plotting Limits
8770  !
8780  LOCATE 20,120,10,93
8790  MAT SORT Freqz(*) TO Point
8800  Fmin=Freqz(Point(0))
8810  Fmax=Freqz(Point(Nf))
8820  MAT SEARCH Pmini(*),MIN;Dbmin
8830  MAT SEARCH Pmaxi(*),MAX;Dbmax
8840  Dbmin=PROUND(Dbmin-.5,0)
8850  Dbmax=PROUND(Dbmax+.5,0)
8860  IF Nf>0 THEN Fc=(Fmax-Fmin)/Nf
```

```
8870  IF Nf=0 THEN Fc=Fmax/2
8880  Fmin=Fmin-Fc
8890  Fmax=Fmax+Fc
8900  SCALE Fmin,Fmax,Dbmin,Dbmax
8910  FRAME
8920  CSIZE 2.75
8930  Y_corr=(Dbmax-Dbmin)*.01
8940  X_corr=(Fmax-Fmin)*.02
8950  Xc=X_corr
8960  CLIP Fmin-X_corr,Fmin,Dbmin,Dbmax
8970  AXES Fc,1,Fmin,Dbmin
8980  UNCLIP
8990  LORG 8
9000  FOR I=Dbmin TO Dbmax                ! ** Label the Y axis **
9010     MOVE Fmin-X_corr*2,I
9020     LABEL USING "#,MDZ";I
9030  NEXT I
9040  LORG 5
9050  LDIR 0
9060  FOR I=0 TO Nf STEP INT(ABS(Nf-1)/10)+1
9070     MOVE Freqz(I),Dbmin-Y_corr
9080     DRAW Freqz(I),Dbmin
9090     MOVE Freqz(I),Dbmin-Y_corr*3
9100     LABEL USING "#,K";Freqz(I)
9110  NEXT I
9120  CSIZE 2.50
9130  IF Nf>15 THEN X_corr=0
9140  FOR J=0 TO Nf
9150     I=Point(J)
9160     LINE TYPE 10
9170     MOVE Freqz(I),Pmini(I)
9180     DRAW Freqz(I),Pmaxi(I)
9190     DRAW Freqz(I),Pmini(I)
9200     LINE TYPE 1
9210  !
9220  ! Mark the Average Error with a Circle
9230  !
9240     LORG 5
9250     LDIR 0
9260     MOVE Freqz(I),Errdbi(I)
9270     LABEL USING "#,K";"O"
9280  !
9290  ! Label the Plot and Dump it to the Graphics Printer
9300  !
9310     LORG 4
9320     IF Nf>15 THEN LORG 2
9330     IF Nf>15 THEN LDIR 90
9340     MOVE Freqz(I)-X_corr,Pmaxi(I)+Y_corr
9350     LABEL USING "#,MDZ.DD";Pmaxi(I)
9360     MOVE Freqz(I)-X_corr,Pmini(I)-Y_corr
9370     LORG 6
9380     IF Nf>15 THEN LORG 8
9390     LABEL USING "#,MDZ.DD";Pmini(I)
9400  NEXT J
9410  X_corr=Xc
9420  LORG 5
9430  CSIZE 3.3
9440  LDIR 90
9450  MOVE Fmin-X_corr*6,(Dbmin+Dbmax)/2
9460  LABEL USING "#,K";"dB Error"
```

```
9470  LDIR 0
9480  X1=(Fmin+Fmax)/2
9490  MOVE X1,Dbmin-Y_corr*8
9500  LABEL USING "#,K";"Frequency (kHz)"
9510  CSIZE 4
9520  MOVE X1,Dbmax+Y_corr*4
9530  LABEL USING "#,K";Title$
9540  PRINT PAGE
9550  DUMP GRAPHICS #10,1
9560  PRINT PAGE
9570  DUMP GRAPHICS #10,1
9580  SUBEND
9590  !
9600  SUB Enterf(INTEGER Nfreq,SHORT Freqx(*))                    *** Enterf
9610 Enterf: !
9620  !
9630  ! SUB Enterf(INTEGER Nfreq,SHORT Freqx(*))
9640  !     Nfreq     Number of Frequencies that were entered (Initially
9650  !               indicates array size)
9660  !     Freqx(*) The actual frequency values in GHz
9670  !
9680  ! Description:
9690  !     Subroutine to enter frequencies from the keyboard into the program
9700  !     array Freqx(*)
9710  !
9720  ! Externals:
9730  !     Dcol      Displays messages on DISP line of CRT (usally errors)
9740  !
9750  DIM Z$[25],A$[160]
9760  SHORT Freq,Inc,Max_freq,Min_freq,Start,Stop
9770  INTEGER C,Cont,I,Nf,Sep,Size,Stopx
9780  PRINTER IS 16
9790  Max_freq=20.0
9800  Min_freq=0
9810  Cont=19       !CONTinue key code
9820  Stopx=52      !STOP key code
9830  !
9840 Enter_freq: Nf=0
9850  DISP "Do you want to enter separate frequencies or a range? (S or R)"
9860  Z$=UPC$(CHR$(READBIN(0)))
9870  IF NUM(Z$)=Stopx THEN STOP
9880  PRINT ""  !Freeze lines above cursor position
9890  IF (Z$="R") OR (NUM(Z$)=Cont) THEN Range
9900  IF Z$<>"S" THEN 9850
9910  ON ERROR GOTO Bad_number
9920  !
9930  !   Enter frequencies Separately
9940  !
9950  Z$=Null$
9960  A$=Null$
9970  Sep=1         !Flag for seperate "mode"
9980  DISP "Enter Frequency (kHz) #";Nf+1;Z$;
9990  LINPUT A$
10000 Size=LEN(A$)
10010 IF Size=0 THEN Exit
10020 FOR I=1 TO Size
10030    Freqx(Nf)=VAL(A$[I])
10040    C=POS(A$[I,Size],",")
10050    IF (Freqx(Nf)>=Min_freq) AND (Freqx(Nf)<=Max_freq) THEN 10080
10060       CALL Dcol("Specified Frequency is out of Range, Try Again...")
```

```
10070     GOTO 9960
10080     Nf=Nf+1
10090     PRINT TAB(60);"Frequency #";Nf;" =";Freqx(Nf-1)
10100     Z$="Press CONTinue to Exit"
10110     IF C=0 THEN 9960
10120     I=I+C-1
10130 NEXT I
10140 !
10150 ! Enter frequencies as a range
10160 !
10170 Range: !
10180 INPUT "Enter Start, Stop, and Increment Frequencies (kHz)",Start,Stop,Inc
10190 IF (Start<Min_freq) OR (Stop>Max_freq) OR (Start>Max_freq) OR (Stop<Min_fr
eq) THEN Range
10200 IF ABS(Stop-Start)/Inc+1<=Nfreq THEN 10230
10210     CALL Dcol("Too many Frequencies! Change dimensioned size.")
10220 GOTO Range
10230 FOR Freq=Start TO Stop STEP Inc
10240     Freqx(Nf)=Freq
10250     Nf=Nf+1
10260 NEXT Freq
10270 Exit: IF Nf>0 THEN 10300
10280     CALL Dcol("No Frequencies Defined! Try Again...")
10290 GOTO Enter_freq
10300 Nfreq=Nf-1
10310 PRINT USING "#,K";""     !Position cursor to first unfrozen line
10320 SUBEXIT
10330 Bad_number: !
10340 IF ERRN<>32 THEN 9960
10350     CALL Dcol("Illegal Numeric Response. Try Again...")
10360 GOTO 9960
10370 SUBEND
10380 !
10390 Set_freq_3314: !                                    *** Set_freq_3314
10400 SUB Set_freq_3314(F_khz)
10410 COM INTEGER Generator,Dmm
10420 IF F_khz=20 THEN F_khz=19.99
10430 F_khz=F_khz*1000
10440 Cmd$="FR"&VAL$(F_khz)&"HZ"
10450 OUTPUT Generator;Cmd$
10460 SUBEXIT
10470 SUBEND
10480 !
10490 Set_amp_3314: !                                     *** Set_amp_3314
10500 SUB Set_amp_3314(Amp)
10510 COM INTEGER Generator,Dmm
10520 IF Amp>=10 THEN 10590
10530 IF Amp<1.0 THEN 10560
10540     Cmd$="AP"&VAL$(Amp)&"VO"
10550     GOTO 10570
10560 Cmd$="AP"&VAL$(Amp*1000)&"MV"
10570 OUTPUT Generator;Cmd$
10580 SUBEXIT
10590 DISP "AMPLITUDE OUT OF RANGE ON 3314"
10600 PAUSE
10610 SUBEND
10620 !
10630 Read_3490: !                                        *** Read 3490
10640 SUB Read_3490(Value)
10650 COM INTEGER Generator,Dmm
```

```
10660 OUTPUT Dmm;"R7F2T1M1E"
10670 ENTER Dmm;A$
10680 Value=VAL(A$[5,14])
10690 SUBEXIT
10700 SUBEND
```

```
10     !  PROGRAM FIELDS          UPDATED: 11/10/83
20     !
30     !  PROGRAM DETERMINES MAGNETIC FIELDS BASED ON JACKSON
40     !
50     PRINTER IS 16
60     OPTION BASE 0
70     DIM Bx(100,200),Bz(100,200)
80     REAL R1,R2,Kr1,Kr2
90     INTEGER B,C
100    SHORT X45,Y45
110    ASSIGN #1 TO "FLDATA:T14"
120    ASSIGN #2 TO "BZ:T15"
130    DISP "Insert 'BX' tape in T14 and 'BZ' tape in T15 and press CONTinue"
140    PAUSE
150    !
160    ! INITIALIZATION AND INPUT
170    !
180    COM A,Kth,Pmimus1,P,Pplus1,Pplus2,Pi,Rp
190    I=1
200    A=.5
210    Kth=-3*PI*I*A^2
220    PRINT "PLEASE DO NOT DISTURB, REMOVE TAPE CARTRIDGE, OR TURN OFF THIS MAC
HINE"
230    PRINTER IS 0
240    PRINT "DISCONTINUITIES IN MAGNETIC FIELDS BASED ON JACKSON"
250    PRINT "SUDDEN ZEROS INDICATING JACKSON FORMULAS ARE NOT PRECISE"
260    PRINT "THE FORMULAS DID NOT CONVERGE AT THE FOLLOWING POINTS";LIN(1)
270    PRINT "  Z         B         Rp        C";LIN(1)
280    B=0
290    FOR Z=-.25 TO .25 STEP .005
300       C=0
310       FOR Rp=0 TO 1 STEP .005
320          DISP Z,Rp
330          Z1=Z
340          R1=SQR(Z1^2+Rp^2)
350          IF R1=0 THEN R1=1E-10
360          Z2=Z-A
370          R2=SQR(Z2^2+Rp^2)
380          IF R2=0 THEN R2=1E-10
390          Kr1=6*PI*I*A/R1
400          Kr2=6*PI*I*A/R2
410          Theta1=ACS(Z1/R1)
420          Theta2=ACS(Z2/R2)
430    !
440    ! CALCULATES MAGNETIC FIELD DUE TO NEAREST COIL
450    !
460 Near_ring:  !
470          Rmax=MAX(A,R1)
480          Rmin=MIN(A,R1)
490          CALL Bfieldr(Kr1,Rmax,Rmin,R1,Z1,Br1,Bth1)
500    !
510    ! CALCULATES MAGNETIC FIELDS DUE TO DISTANT COIL
520    !
530 Far_ring:  !
540          Rmax=MAX(A,R2)
550          Rmin=MIN(A,R2)
560          CALL Bfieldr(Kr2,Rmax,Rmin,R2,Z2,Br2,Bth2)
570 Printout:!
580          IF (Br1=0) OR (Br2=0) THEN Br1=Br2=Bth1=Bth2=0
```

```
590           Bz1=Br1*COS(Theta1)
600           Bz2=Br2*COS(Theta2)
610           Bz3=Bth1*SIN(Theta1)
620           Bz4=Bth2*SIN(Theta2)
630           Bx1=Br1*SIN(Theta1)
640           Bx2=Br2*SIN(Theta2)
650           Bx3=Bth1*COS(Theta1)
660           Bx4=Bth2*COS(Theta2)
670           Bz(B,C)=Bz1+Bz2+Bz3+Bz4
680           Bx(B,C)=Bx1+Bx2-Bx3-Bx4
690           IF (Bz(B,C)=0) AND (Bx(B,C)=0) THEN PRINT USING 780;Z,B,Rp,C
700           C=C+1
710        NEXT Rp
720        B=B+1
730     NEXT Z
740     PRINTER IS 16
750     MAT PRINT #1;Bx
760     MAT PRINT #2;Bz
770     END
780     IMAGE D.DDD,5X,DDD,5X,D.DDD,5X,DDD
790     !
800     ! SUBROUTINE LEGENDRE POLYNOMIAL
810     !
820     ! GENERATES ODD LEGENDRE POLYNOMIAL TERMS FOR Z/R
830     !
840     SUB Leg_poly(R,Zp,N)
850     COM A,Kth,Pminus1,P,Pplus1,Pplus2,Pi,Rp
860     X=Zp/R
870     Pi=0
880     IF (X=1) OR (X=-1) THEN X=SGN(X)*(ABS(X)-1E-9)
890     IF N>0 THEN 930
900           P=1
910           Pplus1=X
920           GOTO 960
930     Pminus1=P
940     P=Pplus2
950     Pplus1=((4*N+1)*X*P-2*N*Pminus1)/(2*N+1)
960     Pplus2=((4*N+3)*X*Pplus1-(2*N+1)*P)/(2*N+2)
970     IF Rp<>0 THEN Pi=(2*N+2)/SQR(1-X*X)*(X*Pplus1-Pplus2)
980     P=Pplus1
990     SUBEXIT
1000    SUBEND
1010    !
1020    ! SUBROUTINE B-FIELD (R VECTOR)
1030    !
1040    ! CALCULATES THE R-VECTOR OF THE MAGNETIC FIELD
1050    !
1060  Bfieldr: !
1070    SUB Bfieldr(K,G,L,R,Zp,Br,Bft)
1080    COM A,Kth,Pminus1,P,Pplus1,Pplus2,Pi,Rp
1090    Br=Bft=N=0
1100    J=-1
1110    CALL Leg_poly(R,Zp,N)
1120    J=-J
1130    IF N=0 THEN Bf=K*L^(2*N+1)*P/G^(2*N+2)
1140    IF N<>0 THEN Bf=K*J*FNFactr(N)*L^(2*N+1)*P/(2^N*G^(2*N+2))
1150    IF A=R THEN 1240
1160    IF A>R THEN Ba=Kth*J*FNFactth(N)*Pi*-(2*N+2)*(R/A)^(2*N)/(2^N*(2*N+1)*A^3)
1170    IF A<R THEN Ba=Kth*J*FNFactth(N)*Pi*(A/R)^(2*N)/(2^N*R^3)
1180          Br=Br+Bf
```

```
1190        Bft=Bft+Ba
1200        IF ABS(Bf)<=1E-4 THEN SUBEXIT
1210             N=N+1
1220             IF N>200 THEN 1240
1230             GOTO 1110
1240   Br=Bft=0
1250   SUBEXIT
1260   SUBEND
1270   !
1280   ! FUNCTION FACTORIAL R-VECTOR
1290   !
1300   ! CALCULATES RESULT OF FACTORIAL DIVISION FOR R-VECTOR OF JACKSON
1310   !
1320   DEF FNFactr(N)
1330   K=N
1340   F=2*K+1
1350   L=2*K-1
1360   IF K MOD 2 THEN K=K-1
1370 Testr: !
1380   IF (K=0) OR (L=0) THEN Endr
1390        F=F*(L/K)
1400        L=L-2
1410        K=K-2
1420        GOTO Testr
1430 Endr:!
1440   RETURN F
1450   FNEND
1460   !
1470   ! FUNCTION FACTORIAL Theta-VECTOR
1480   !
1490   ! CALCULATES RESULT OF FACTORIAL DIVISION FOR Theta-VECTOR OF JACKSON
1500   !
1510 Factth: !
1520   DEF FNFactth(N)
1530   K=N
1540   F=1
1550   L=2*K+1
1560   IF K MOD 2 THEN K=K+1
1570 Testth: !
1580   IF (K=0) OR (L=0) THEN Endth
1590        F=F*(L/K)
1600        L=L-2
1610        K=K-2
1620        GOTO Testth
1630 Endth:!
1640   RETURN F
1650   FNEND
```

```
10     !  PROGRAM INTERP
20     !
30     !  This program uses cubic spline interpolation to fill in values
40     !  where the Jackson formulas did not converge.
50     !
60     DIM Bz(100,200),Index(50),X(200),Y(200),Domain(50),Deriv(50),Func(50)
70     ASSIGN #1 TO "FLDBZ:T14"
80     READ #1;Bz(*)
90     Eps=1E-6
100    !
110    !  Interpolating the rows is done here.
120    !
130    FOR I=0 TO 100
140       DISP "WORKING ON ROW ";I
150       Valx=0
160       Index1=Index2=0
170       FOR J=0 TO 200
180          IF Bz(I,J)<>0 THEN 240
190             Index1=Index1+1
200             Domain(Index1)=Valx
210             Index(Index1)=J
220             IF (Index1)50) OR (Index2=0) THEN 340
230             GOTO 270
240          Index2=Index2+1
250          X(Index2)=Valx
260          Y(Index2)=Bz(I,J)
270          Valx=Valx+.005
280       NEXT J
290       IF Index1=0 THEN 340
300          CALL Spline(Index2,Index1,X(*),Y(*),Domain(*),Func(*),Deriv(*),Int,E
ps)
310          FOR J=1 TO Index1
320             Bz(I,Index(J))=Func(J)
330          NEXT J
340    NEXT I
350    !
360    ! Interpolating the columns, and incidently all remaining unknown values,
370    ! is done here.
380    !
390    FOR J=0 TO 200
400       DISP "WORKING ON COLUMN ";J
410       Valx=-.25
420       Index1=Index2=0
430       FOR I=0 TO 100
440          IF Bz(I,J)<>0 THEN 490
450             Index1=Index1+1
460             Domain(Index1)=Valx
470             Index(Index1)=I
480             GOTO 520
490          Index2=Index2+1
500          X(Index2)=Valx
510          Y(Index2)=Bz(I,J)
520          Valx=Valx+.005
530       NEXT I
540       IF Index1=0 THEN 590
550          CALL Spline(Index2,Index1,X(*),Y(*),Domain(*),Func(*),Deriv(*),Int,E
ps)
560          FOR I=1 TO Index1
570             Bz(Index(I),J)=Func(I)
```

```
580          NEXT I
590     NEXT J
600     REWIND ":T14"
610     PRINT #1;Bz(*)
620     END
630   SUB Spline(N,Narg,X(*),Y(*),Domain(*),Func(*),Deriv(*),Int,Eps)
640   !
650   ! ************************************************************************
660   ! *** SPLINE FIT FOR FUNCTION VALUES, INTEGRATION AND DIFFERENTIATION.
670   ! ************************************************************************
680   !
690   !
700   ! *** BAD DATA CHECK.
710   Baddta=(N<=0) OR (Eps<=0)
720   IF Baddta=0 THEN 820
730   ! *** PRINT ERROR MESSAGE AND PAUSE.
740   ! *** USER MAY CORRECT DATA AND CONTINUE.
750   PRINT LIN(2),"ERROR IN SUBPROGRAM Spline."
760   PRINT "N=";N,"Eps=";Eps,LIN(2)
770   PAUSE
780   GOTO 710
790   !
800   !
810   ! *** BEGIN SUBPROGRAM.
820   OPTION BASE 1
830   DIM S(N),G(N-1),Work(N-1)
840   FOR I=2 TO N-1
850      Xi=X(I)
860      Xim1=X(I-1)
870      Xip1=X(I+1)
880      Yi=Y(I)
890      Yim1=Y(I-1)
900      Yip1=Y(I+1)
910      X=Xi-Xim1
920      H=Xip1-Xim1
930      Work(I)=.5*X/H
940      T=((Yip1-Yi)/(Xip1-Xi)-(Yi-Yim1)/X)/H
950      S(I)=2*T
960      G(I)=3*T
970   NEXT I
980   S(1)=S(N)=0
990   ! *** W IS THE RELAXATION FACTOR FOR SUCCESSIVE OVER-RELAXATION.
1000  W=8-4*SQR(3)
1010  U=0
1020  FOR I=2 TO N-1
1030     T=W*(-S(I)-Work(I)*S(I-1)-(.5-Work(I))*S(I+1)+G(I))
1040     H=ABS(T)
1050     IF H>U THEN U=H
1060     S(I)=S(I)+T
1070  NEXT I
1080  IF U>=Eps THEN 1010
1090  FOR I=1 TO N-1
1100     G(I)=(S(I+1)-S(I))/(X(I+1)-X(I))
1110  NEXT I
1120  IF Narg=0 THEN 1440
1130  !
1140  !
1150  ! *** CALCULATE FUNCTION VALUES AND DERIVATIVES.
1160  FOR J=1 TO Narg
1170  Corrector:     I=1
```

```
1180     T=Domain(J)
1190     IF T>=X(1) THEN 1270
1200     PRINT LIN(2),"ERROR IN SUBPROGRAM Spline."
1210     PRINT "ARGUMENT OUT OF BOUNDS."
1220     PRINT "X(1)=";X(1),"X(N)=";X(N),"Domain(";J;")=";Domain(J),LIN(2)
1230     PAUSE
1240     GOTO 1170
1250     !
1260     !
1270     I=I+1
1280     IF I>N THEN 1200
1290     IF T>X(I) THEN 1270
1300     I=I-1
1310     H=Domain(J)-X(I)
1320     T=Domain(J)-X(I+1)
1330     X=H*T
1340     S=S(I)+H*G(I)
1350     Z=1/6
1360     U=Z*(S(I)+S(I+1)+S)
1370     W=(Y(I+1)-Y(I))/(X(I+1)-X(I))
1380     Func(J)=W*H+Y(I)+X*U
1390     Deriv(J)=W+(H+T)*U+Z*X*G(I)
1400 NEXT J
1410 !
1420 !
1430 ! *** CALCULATE INTEGRAL FROM X(1) TO X(N).
1440 Int=0
1450 FOR I=1 TO N-1
1460     H=X(I+1)-X(I)
1470     Int=Int+.5*H*(Y(I)+Y(I+1))-1/24*H^3*(S(I)+S(I+1))
1480 NEXT I
1490 SUBEND
```

APPENDIX B

Table of Values for the

Magnetic Field

in a

Helmholtz coil

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.000	.005	.010	.015	.020	.025	.030	.035	.040	.045	.050	.055
0.000	0.0000	-.1113	-.1832	-.2973	-.3970	-.4690	-.6029	-.6968	-.8084	-.9027	-.9709	-1.0757
0.005	0.0000	-.1046	-.1807	-.2856	-.3804	-.4558	-.5785	-.6671	-.7733	-.8633	-.9333	-1.0329
0.010	0.0000	-.0974	-.1786	-.2739	-.3643	-.4453	-.5534	-.6382	-.7372	-.8240	-.8990	-.9926
0.015	0.0000	-.0902	-.1752	-.2619	-.3487	-.4338	-.5273	-.6105	-.7011	-.7852	-.8650	-.9526
0.020	0.0000	-.0835	-.1688	-.2495	-.3330	-.4176	-.5006	-.5835	-.6661	-.7475	-.8287	-.9109
0.025	0.0000	-.0792	-.1601	-.2389	-.3170	-.3977	-.4761	-.5551	-.6328	-.7113	-.7882	-.8660
0.030	0.0000	-.0758	-.1510	-.2281	-.3014	-.3767	-.4524	-.5266	-.6021	-.6752	-.7485	-.8214
0.035	0.0000	-.0717	-.1432	-.2150	-.2859	-.3566	-.4278	-.4993	-.5721	-.6388	-.7114	-.7783
0.040	0.0000	-.0678	-.1355	-.2030	-.2689	-.3379	-.4038	-.4716	-.5367	-.6037	-.6678	-.7309
0.045	0.0000	-.0639	-.1251	-.1917	-.2559	-.3187	-.3816	-.4447	-.5072	-.5679	-.6304	-.6907
0.050	0.0000	-.0603	-.1216	-.1806	-.2408	-.2985	-.3595	-.4190	-.4749	-.5353	-.5925	-.6489
0.055	0.0000	-.0567	-.1138	-.1698	-.2260	-.2828	-.3378	-.3928	-.4478	-.5021	-.5559	-.6085
0.060	0.0000	-.0532	-.1065	-.1592	-.2119	-.2641	-.3165	-.3759	-.4196	-.4698	-.5195	-.5684
0.065	0.0000	-.0498	-.0995	-.1444	-.1982	-.2473	-.2949	-.3440	-.3914	-.4390	-.4864	-.5304
0.070	0.0000	-.0464	-.0926	-.1369	-.1848	-.2305	-.2753	-.3204	-.3577	-.4083	-.4508	-.4929
0.075	0.0000	-.0432	-.0862	-.1305	-.1719	-.2143	-.2564	-.2974	-.3385	-.3789	-.4177	-.4578
0.080	0.0000	-.0401	-.0802	-.1204	-.1595	-.1987	-.2374	-.2753	-.3134	-.3503	-.3864	-.4218
0.085	0.0000	-.0371	-.0741	-.1105	-.1474	-.1836	-.2193	-.2549	-.2904	-.3231	-.3562	-.3879
0.090	0.0000	-.0342	-.0684	-.1025	-.1325	-.1917	-.2020	-.2341	-.2660	-.2969	-.3332	-.3563
0.095	0.0000	-.0314	-.0628	-.0938	-.1248	-.1553	-.1854	-.2150	-.2432	-.2718	-.2989	-.3253
0.100	0.0000	-.0288	-.0575	-.0861	-.1143	-.1421	-.1695	-.1962	-.2222	-.2487	-.2724	-.2958
0.105	0.0000	-.0263	-.0524	-.0784	-.1050	-.1295	-.1544	-.1785	-.2024	-.2250	-.2470	-.2680
0.110	0.0000	-.0239	-.0477	-.0713	-.0950	-.1124	-.1400	-.1618	-.1829	-.2030	-.2219	-.2414
0.115	0.0000	-.0216	-.0432	-.0644	-.0851	-.1062	-.1264	-.1460	-.1648	-.1828	-.2002	-.2165
0.120	0.0000	-.0195	-.0388	-.0581	-.0767	-.0955	-.1136	-.1309	-.1478	-.1639	-.1788	-.1929
0.125	0.0000	-.0175	-.0349	-.0520	-.0691	-.0854	-.1015	-.1169	-.1316	-.1458	-.1591	-.1709
0.130	0.0000	-.0156	-.0311	-.0464	-.0615	-.0773	-.0902	-.0811	-.1167	-.1287	-.1402	-.1509
0.135	0.0000	-.0138	-.0276	-.0411	-.0542	-.0680	-.0797	-.0916	-.1027	-.1130	-.1224	-.1315
0.140	0.0000	-.0122	-.0243	-.0362	-.0480	-.0596	-.0699	-.0801	-.0897	-.0986	-.1064	-.1135
0.145	0.0000	-.0107	-.0213	-.0316	-.0419	-.0510	-.0609	-.0696	-.0778	-.0852	-.0916	-.0970
0.150	0.0000	-.0093	-.0185	-.0275	-.0362	-.0443	-.0526	-.0600	-.0668	-.0728	-.0782	-.0822
0.155	0.0000	-.0080	-.0159	-.0237	-.0311	-.0381	-.0451	-.0512	-.0573	-.0617	-.0658	-.0688
0.160	0.0000	-.0069	-.0136	-.0202	-.0267	-.0329	-.0395	-.0432	-.0478	-.0516	-.0545	-.0569
0.165	0.0000	-.0058	-.0115	-.0171	-.0225	-.0276	-.0320	-.0360	-.0397	-.0425	-.0446	-.0459
0.170	0.0000	-.0049	-.0097	-.0143	-.0186	-.0229	-.0265	-.0296	-.0324	-.0344	-.0358	-.0363
0.175	0.0000	-.0040	-.0080	-.0118	-.0153	-.0185	-.0216	-.0241	-.0260	-.0273	-.0280	-.0277
0.180	0.0000	-.0033	-.0065	-.0096	-.0125	-.0149	-.0167	-.0191	-.0204	-.0211	-.0211	-.0205
0.185	0.0000	-.0026	-.0052	-.0077	-.0099	-.0118	-.0132	-.0148	-.0155	-.0158	-.0154	-.0144
0.190	0.0000	-.0021	-.0041	-.0060	-.0077	-.0093	-.0101	-.0096	-.0109	-.0113	-.0105	-.0092
0.195	0.0000	-.0016	-.0032	-.0046	-.0058	-.0070	-.0075	-.0081	-.0080	-.0075	-.0065	-.0049
0.200	0.0000	-.0012	-.0024	-.0034	-.0044	-.0050	-.0057	-.0057	-.0052	-.0045	-.0033	-.0015
0.205	0.0000	-.0009	-.0017	-.0025	-.0031	-.0034	-.0038	-.0035	-.0030	-.0021	-.0008	0.0011
0.210	0.0000	-.0006	-.0012	-.0017	-.0021	-.0022	-.0023	-.0019	0.0018	-.0004	0.0010	0.0028
0.215	0.0000	-.0004	-.0008	-.0011	-.0013	-.0013	-.0013	-.0015	-.0001	0.0009	0.0022	0.0039
0.220	0.0000	-.0003	-.0005	-.0006	-.0007	-.0007	-.0002	-.0004	0.0001	0.0016	0.0029	0.0045
0.225	0.0000	-.0001	-.0003	-.0003	-.0003	-.0002	0.0002	0.0007	0.0011	0.0020	0.0031	0.0045
0.230	0.0000	-.0001	-.0001	-.0001	-.0001	0.0001	0.0004	0.0010	0.0013	0.0020	0.0030	0.0041
0.235	0.0000	-.0000	-.0000	-.0000	0.0000	0.0003	0.0004	0.0007	0.0012	0.0018	0.0025	0.0034
0.240	0.0000	-.0000	-.0000	0.0000	0.0001	0.0003	0.0004	0.0005	0.0009	0.0013	0.0018	0.0024
0.245	0.0000	-.0000	-.0000	0.0000	0.0001	0.0002	0.0001	0.0005	-.0007	0.0007	0.0009	0.0012
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.060	.065	.070	.075	.080	.085	.090	.095	.100	.105	.110	.115
0.000	-1.1963	-1.2887	-1.4108	-1.4835	-1.5913	-1.6003	-1.7877	-1.8697	-1.9796	-2.6174	-2.1836	-2.2754
0.005	-1.1451	-1.2260	-1.3487	-1.4201	-1.5206	-1.5411	-1.7004	-1.7773	-1.8852	-3.3148	-2.0808	-2.1638
0.010	-1.0940	-1.1665	-1.2839	-1.3598	-1.4506	-1.4928	-1.6150	-1.6944	-1.7931	-3.7452	-1.9773	-2.0540
0.015	-1.0431	-1.1136	-1.2186	-1.2993	-1.3810	-1.4452	-1.5351	-1.6171	-1.7040	-3.3811	-1.8740	-1.9479
0.020	-.9924	-1.0709	-1.1550	-1.2357	-1.3121	-1.3882	-1.4647	-1.5416	-1.6185	-1.6952	-1.7717	-1.8476
0.025	-.9419	-.9832	-1.0942	-1.1730	-1.2444	-1.3194	-1.3918	-1.4635	-1.5335	-1.2364	-1.6737	-1.7392
0.030	-.8924	-.9315	-1.0361	-1.1099	-1.1772	-1.2472	-1.3153	-1.3828	-1.4483	-1.5138	-1.5793	-1.6328
0.035	-.8443	-.9516	-.9802	-1.0456	-1.1110	-1.1779	-1.2389	-1.3015	-1.3633	-1.4228	-1.4851	-1.5390
0.040	-.7965	-.8614	-.9238	-.9851	-1.0481	-1.1056	-1.1652	-1.2229	-1.2793	-1.3339	-1.3872	-1.4442
0.045	-.7511	-.8093	-.8687	-.9260	-.9819	-1.0375	-1.0922	-1.1433	-1.1978	-1.2469	-1.2944	-1.3425
0.050	-.7052	-.7605	-.8150	-.8691	-.9201	-.9696	-1.0236	-1.0691	-1.1158	-1.1623	-1.2055	-1.2467
0.055	-.6607	-.7117	-.7617	-.8078	-.8602	-.9058	-.9515	-.9948	-1.0378	-1.0783	-1.1161	-1.1542
0.060	-.6171	-.6641	-.7106	-.7557	-.7999	-.8427	-.8857	-.9243	-.9619	-.9976	-1.0306	-1.0655
0.065	-.5753	-.6171	-.6607	-.7028	-.7422	-.7814	-.8184	-.8537	-.8875	-.9183	-.9497	-.9775
0.070	-.5340	-.5739	-.6128	-.6505	-.6861	-.7213	-.7544	-.7863	-.8159	-.8413	-.8700	-.8937
0.075	-.4941	-.5310	-.5662	-.5987	-.6331	-.6646	-.6948	-.7213	-.7474	-.7714	-.7933	-.8120
0.080	-.4560	-.4891	-.5209	-.5518	-.5812	-.6089	-.6346	-.6589	-.6813	-.7018	-.7191	-.7348
0.085	-.4194	-.4494	-.4782	-.5058	-.5312	-.5554	-.5778	-.5987	-.6173	-.6343	-.6489	-.6599
0.090	-.3846	-.4110	-.4368	-.4611	-.4841	-.5058	-.5239	-.5411	-.5567	-.5712	-.5807	-.5889
0.095	-.3507	-.3744	-.3971	-.4183	-.4382	-.4561	-.4725	-.4866	-.4986	-.5088	-.5163	-.5217
0.100	-.3181	-.3391	-.3595	-.3780	-.3947	-.4101	-.4241	-.4349	-.4439	-.4511	-.4564	-.4577
0.105	-.2879	-.3062	-.3231	-.3396	-.3539	-.3661	-.3770	-.3865	-.3906	-.3962	-.3982	-.3971
0.110	-.2589	-.2752	-.2898	-.3024	-.3151	-.3249	-.3329	-.3399	-.3434	-.3449	-.3441	-.3407
0.115	-.2315	-.2455	-.2582	-.2689	-.2784	-.2863	-.2919	-.2958	-.2974	-.2969	-.2934	-.2881
0.120	-.2059	-.2175	-.2282	-.2369	-.2434	-.2498	-.2537	-.2550	-.2552	-.2518	-.2465	-.2388
0.125	-.1818	-.1917	-.1999	-.2072	-.2118	-.2159	-.2177	-.2173	-.2152	-.2102	-.2031	-.1929
0.130	-.1595	-.1674	-.1812	-.1792	-.1826	-.1843	-.1844	-.1824	-.1784	-.1719	-.1630	-.1513
0.135	-.1386	-.1448	-.1499	-.1534	-.1552	-.1554	-.1538	-.1503	-.1444	-.1366	-.1262	-.1133
0.140	-.1203	-.1242	-.1276	-.1295	-.1302	-.1285	-.1265	-.1195	-.1138	-.1048	-.0926	-.0788
0.145	-.1018	-.1051	-.1071	-.1079	-.1071	-.1044	-.1003	-.0935	-.0879	-.0758	-.0628	-.0482
0.150	-.0856	-.0877	-.1285	-.0882	-.0862	-.0826	-.0774	-.0703	-.0611	-.0497	-.0362	-.0205
0.155	-.0710	-.0730	-.0699	-.0704	-.0675	-.0632	-.0565	-.0489	-.0389	-.0269	-.0129	0.0038
0.160	-.0576	-.0586	-.0569	-.0545	-.0508	-.0456	-.0385	-.0305	-.0195	-.0052	0.0076	0.0247
0.165	-.0460	-.0455	-.0436	-.0405	-.0362	-.0305	-.0227	-.0140	-.0028	0.0101	0.0251	0.0424
0.170	-.0357	-.0345	-.0320	-.0283	-.0234	-.0169	-.0091	0.0003	0.0120	0.0246	0.0397	0.0569
0.175	-.0270	-.0249	-.0219	-.0177	-.0124	-.0057	0.0023	0.0120	0.0234	0.0365	0.0515	0.0685
0.180	-.0191	-.0164	-.0139	-.0088	-.0031	0.0036	0.0118	0.0217	0.0329	0.0453	0.0606	0.0772
0.185	-.0125	-.0096	-.0065	-.0004	0.0044	0.0112	0.0194	0.0292	0.0401	0.0528	0.0672	0.0833
0.190	-.0069	-.0040	-.0003	0.0045	0.0102	0.0171	0.0253	0.0347	0.0451	0.0576	0.0720	0.0870
0.195	-.0025	0.0005	0.0043	0.0090	0.0134	0.0217	0.0293	0.0383	0.0485	0.0603	0.0735	0.0882
0.200	0.0009	0.0038	0.0077	0.0123	0.0179	0.0243	0.0318	0.0403	0.0500	0.0613	0.0735	0.0873
0.205	0.0034	0.0063	0.0103	0.0145	0.0197	0.0258	0.0328	0.0408	0.0499	0.0603	0.0716	0.0843
0.210	0.0051	0.0080	0.0116	0.0156	0.0204	0.0261	0.0325	0.0399	0.0483	0.0577	0.0680	0.0796
0.215	0.0061	0.0089	0.0121	0.0155	0.0200	0.0253	0.0311	0.0378	0.0453	0.0537	0.0627	0.0732
0.220	0.0064	0.0090	0.0118	0.0149	0.0190	0.0235	0.0287	0.0355	0.0410	0.0484	0.0564	0.0656
0.225	0.0063	0.0084	0.0107	0.0137	0.0175	0.0209	0.0253	0.0302	0.0358	-.3906	0.0489	0.0566
0.230	0.0056	0.0073	0.0092	0.0117	0.0144	0.0172	0.0211	0.0251	0.0296	0.0346	0.0403	0.0468
0.235	0.0045	0.0057	0.0073	0.0093	0.0113	0.0137	0.0163	0.0194	0.0228	0.0266	0.0310	0.0358
0.240	0.0032	0.0040	0.0050	0.0065	0.0079	0.0087	0.0111	0.0132	0.0155	0.0180	0.0210	0.0242
0.245	0.0016	0.0021	0.0025	0.0033	0.0042	0.0047	0.0056	0.0085	0.0078	0.0092	0.0106	0.0123
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.120	.125	.130	.135	.140	.145	.150	.155	.160	.165	.170	.175
0.000	-2.5590	-2.7931	-2.9795	-3.1335	-2.6325	-2.7351	-2.9834	-3.0705	-3.1620	-3.2518	-3.3226	-3.4163
0.005	-2.7180	-3.1482	-3.4636	-3.6881	-2.6153	-2.7082	-2.7966	-2.8793	-2.9686	-3.0543	-3.1377	-3.2222
0.010	-2.7859	-3.3442	-3.7435	-4.0108	-3.1046	-3.1757	-2.6387	-2.7202	-2.7984	-2.8758	-2.9512	-3.0227
0.015	-2.5812	-3.0657	-3.4142	-3.6470	-3.3176	-3.3730	-2.9630	-2.9830	-2.9848	-2.9786	-2.7645	-2.8311
0.020	-1.9228	-1.9971	-2.0702	-2.1421	-2.2125	-2.2811	-2.3479	-2.4126	-2.4750	-2.5349	-2.5921	-2.6465
0.025	-1.6797	-1.6607	-1.6646	-1.6946	-1.8262	-1.8961	-2.0607	-2.1378	-2.2166	-2.2920	-2.4290	-2.4732
0.030	-1.7011	-1.7642	-1.8231	-1.8814	-1.9402	-1.9992	-2.0577	-2.1147	-2.1695	-2.2213	-2.2693	-2.3126
0.035	-1.6108	-1.6495	-1.7020	-1.7515	-1.8016	-1.8475	-1.8945	-1.9437	-1.9938	-2.0437	-2.0920	-2.1374
0.040	-1.4905	-1.5393	-1.5860	-1.6296	-1.6731	-1.7031	-1.7516	-1.7879	-1.8164	-1.8431	-1.8682	-1.8912
0.045	-1.3865	-1.4305	-1.4721	-1.5119	-1.5477	-1.5826	-1.6136	-1.6426	-1.6374	-1.7055	-1.7096	-1.7235
0.050	-1.2730	-1.3246	-1.3618	-1.3939	-1.4252	-1.4527	-1.4782	-1.5012	-1.5203	-1.5265	-1.5477	-1.5593
0.055	-1.1896	-1.2224	-1.2524	-1.2803	-1.3057	-1.3283	-1.3470	-1.3639	-1.3761	-1.3843	-1.3904	-1.3927
0.060	-1.0949	-1.1227	-1.1468	-1.1678	-1.1902	-1.2067	-1.2191	-1.2312	-1.2374	-1.2383	-1.2385	-1.2311
0.065	-1.0031	-1.0264	-1.0474	-1.0640	-1.0788	-1.0903	-1.0985	-1.1212	-1.1043	-1.1001	-1.0920	-1.0794
0.070	-.9153	-.9327	-.9487	-.9617	-.9717	-.9780	-.9808	-.9794	-.9745	-.9655	-.9508	-.9330
0.075	-.8292	-.8435	-.8545	-.8621	-.8678	-.8695	-.8683	-.8622	-.8519	-.8366	-.8184	-.7929
0.080	-.7471	-.7574	-.7647	-.7687	-.7685	-.7662	-.7596	-.7495	-.7343	-.7141	-.6896	-.6632
0.085	-.6694	-.6751	-.6784	-.6810	-.6752	-.6678	-.6568	-.6417	-.6222	-.5982	-.5685	-.5340
0.090	-.5933	-.5975	-.5964	-.5927	-.5857	-.5747	-.5614	-.5402	-.5164	-.4880	-.4541	-.4145
0.095	-.5235	-.5230	-.5191	-.5116	-.5012	-.4864	-.4673	-.4444	-.4172	-.3846	-.3468	-.3034
0.100	-.4567	-.4521	-.4522	-.4332	-.4211	-.4031	-.3810	-.3547	-.3236	-.2876	-.2464	-.1995
0.105	-.3937	-.3868	-.3769	-.3637	-.3462	-.3255	-.3000	-.2706	-.2367	-.1989	-.1526	-.1032
0.110	-.3262	-.3249	-.3123	-.2964	-.2763	-.2533	-.2250	-.1928	-.1559	-.1138	-.0665	-.0138
0.115	-.2785	-.2684	-.2521	-.2343	-.2116	-.1856	-.1556	-.1216	-.0818	-.0373	0.0124	0.0679
0.120	-.2278	-.2140	-.1967	-.1762	-.1521	-.1247	-.0915	-.0548	-.0137	0.0331	0.0846	0.1414
0.125	-.1804	-.1647	-.1459	-.1234	-.0973	-.0673	-.0325	0.0049	0.0482	0.0961	0.1490	0.2079
0.130	-.1371	-.1194	-.0992	-.0751	-.0479	-.0163	0.0191	0.0580	0.1034	0.1525	0.2070	0.2670
0.135	-.0976	-.0784	-.0573	-.0317	-.0031	0.0280	0.0663	0.1071	0.1523	0.2025	0.2579	0.3175
0.140	-.0617	-.0419	-.0190	0.0076	0.0369	0.0705	0.1075	0.1492	0.1952	0.2464	0.3018	0.3625
0.145	-.0298	-.0093	0.0146	0.0420	0.0720	0.1061	0.1335	0.1858	0.2323	0.2823	0.3386	0.3997
0.150	-.0011	0.0197	0.0442	0.0716	0.1026	0.1366	0.1747	0.2171	0.2798	0.3139	0.3694	0.4303
0.155	0.0233	0.0448	0.0695	0.0970	0.1281	0.1638	0.2007	0.2426	0.2883	0.3416	0.3944	0.4537
0.160	0.0498	0.0656	0.0909	0.1185	0.1495	0.1837	0.2227	0.2629	0.3081	0.3579	0.4119	0.4704
0.165	0.0618	0.0837	0.1085	0.1360	0.1667	0.2004	0.2371	0.2780	0.3236	0.3714	0.4240	0.4806
0.170	0.0761	0.0979	0.1229	0.1496	0.1796	0.2126	0.2488	0.2886	0.3319	0.3792	0.4303	0.4858
0.175	0.0874	0.1090	0.1327	0.1594	0.1886	0.2206	0.2559	0.2947	0.3363	0.3816	0.4310	0.4847
0.180	0.0958	0.1169	0.1400	0.1647	0.1937	0.2247	0.2587	0.2957	0.3360	0.3795	0.4265	0.4782
0.185	0.1015	0.1216	0.1438	0.1684	0.1955	0.2251	0.2577	0.2928	0.3311	0.3727	0.4177	0.4666
0.190	0.1044	0.1235	0.1445	0.1681	0.1938	0.2220	0.2527	0.2860	0.3220	0.3614	0.4101	0.4499
0.195	0.1047	0.1228	0.1427	0.1648	0.1894	0.2049	0.2442	0.2754	0.3094	0.3461	0.3858	0.4286
0.200	0.1026	0.1197	0.1382	0.1588	0.1813	0.2058	0.2317	0.2614	0.2931	0.3272	0.3637	0.4032
0.205	0.0985	0.1141	0.1313	0.1504	0.1709	0.1934	0.2178	0.2444	0.2732	0.3048	0.3378	0.3739
0.210	0.0925	0.1067	0.1224	0.1395	0.1581	0.1781	0.2005	0.2245	0.2506	0.2785	0.3087	0.3408
0.215	0.0848	0.0975	0.1114	0.1271	0.1430	0.1612	0.1808	0.2022	0.2252	0.2500	0.2767	0.3055
0.220	0.0760	0.0866	0.0987	0.1119	0.1262	0.1420	0.1590	0.1774	0.1975	0.2190	0.2419	0.2679
0.225	0.0648	0.0743	0.0845	0.0956	0.1077	0.1210	0.1357	0.1507	0.1677	0.1856	0.2053	0.2262
0.230	0.0533	0.0606	0.0690	0.0780	0.0879	0.0986	0.1101	0.1226	0.1359	0.1497	0.1665	0.1834
0.235	0.0408	0.0464	0.0526	0.0595	0.0669	0.0751	0.0837	0.0931	0.1033	0.1143	0.1262	0.1391
0.240	0.0275	0.0313	0.0350	0.0401	0.0471	0.0506	0.0592	0.0626	0.0694	0.0763	0.0848	0.0935
0.245	0.0136	0.0158	0.0179	0.0202	0.0227	0.0254	0.0284	0.0311	0.0349	0.0386	0.0426	0.0468
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.180	.185	.190	.195	.200	.205	.210	.215	.220	.225	.230	.235
0.000	-3.5103	-3.6026	-3.6936	-3.7804	-3.8754	-3.9827	-4.0500	-4.1403	-4.2310	-4.3133	-4.3996	-4.4835
0.005	-3.3043	-3.3853	-3.4668	-3.5405	-3.6254	-3.7022	-3.7753	-3.8522	-3.9252	-3.9966	-4.0666	-4.1336
0.010	-3.0989	-3.1698	-3.2405	-3.3096	-3.3763	-3.4414	-3.5058	-3.5663	-3.6245	-3.6811	-3.7359	-3.7875
0.015	-2.8952	-2.9562	-3.0154	-3.0742	-3.1301	-3.1832	-3.2324	-3.2821	-3.3277	-3.3695	-3.4087	-3.4437
0.020	-2.6978	-2.7458	-2.7951	-2.8526	-2.8866	-2.9290	-2.9675	-2.9717	-3.0335	-3.0620	-3.0854	-3.1049
0.025	-2.5136	-2.5488	-2.5820	-2.6175	-2.6327	-2.6555	-2.6810	-2.6856	-2.7326	-2.7586	-2.7681	-2.7992
0.030	-2.3505	-2.3822	-2.4068	-2.4237	-2.4328	-2.4385	-2.4460	-2.4556	-2.4572	-2.4609	-2.4563	-2.4809
0.035	-2.1788	-2.2148	-2.2443	-2.2660	-2.2785	-2.2808	-2.2714	-2.2492	-2.2129	-2.1711	-2.1518	-2.1258
0.040	-1.9115	-1.9287	-1.9422	-1.9516	-1.9563	-1.9558	-1.9495	-1.9371	-1.9179	-1.8915	-1.8573	-1.8157
0.045	-1.7194	-1.7140	-1.7137	-1.7158	-1.7175	-1.7159	-1.7082	-1.6916	-1.6634	-1.6206	-1.5605	-1.4862
0.050	-1.5603	-1.5567	-1.5490	-1.5365	-1.5186	-1.4951	-1.4656	-1.4297	-1.3870	-1.3373	-1.2801	-1.2151
0.055	-1.3876	-1.3781	-1.3656	-1.3463	-1.3189	-1.2720	-1.2210	-1.1693	-1.1152	-1.0570	-.9931	-.9217
0.060	-1.2212	-1.2017	-1.1842	-1.1572	-1.1232	-1.0837	-1.0520	-1.0123	-.9595	-.8937	-.8148	-.7229
0.065	-1.0616	-1.0395	-1.0088	-.9754	-.9340	-.8876	-.8310	-.7696	-.6966	-.6088	-.5137	-.4121
0.070	-.9089	-.8754	-.8440	-.8025	-.7548	-.6994	-.6347	-.3276	-.4907	-.4121	-.2448	-.0919
0.075	-.7621	-.7281	-.6856	-.6388	-.5835	-.5204	-.4499	-.3704	-.2836	-.1723	-.0809	0.0390
0.080	-.6245	-.5834	-.5694	-.4826	-.4232	-.3532	-.2584	-.1888	-.0945	0.0103	0.1242	0.2500
0.085	-.4941	-.4495	-.3946	-.3325	-.2678	-.1950	-.1101	-.0178	0.0815	0.1943	0.3147	0.4454
0.090	-.3702	-.3188	-.2605	-.1963	-.0819	-.0438	0.0437	0.1434	0.2477	0.3639	0.4919	0.6331
0.095	-.2546	-.1937	-.1370	-.0683	0.0085	0.0984	0.1876	0.2883	0.3994	0.5217	0.6542	0.7983
0.100	-.1463	-.0873	-.0217	0.0517	0.1318	0.2203	0.3177	0.4235	0.5398	0.6652	0.8027	0.8399
0.105	-.0468	0.0157	0.0851	0.1609	0.2458	0.3372	0.4369	0.5475	0.6659	0.8001	0.9360	1.0892
0.110	0.0454	0.1105	0.1822	0.2620	0.3484	0.4428	0.5469	0.6567	0.7800	0.9130	1.0562	1.2106
0.115	0.1291	0.1965	0.2712	0.3524	0.4412	0.5390	0.6439	0.7583	0.8826	1.0162	1.1618	1.3175
0.120	0.2047	0.2746	0.3506	0.4334	0.5244	0.6231	0.7298	0.8525	0.9713	1.1068	1.2528	1.4102
0.125	0.2730	0.3437	0.4208	0.5055	0.5975	0.6966	0.8052	0.9220	1.0475	1.1842	1.3302	1.4878
0.130	0.3327	0.4042	0.4829	0.5682	0.6591	0.7607	0.8697	0.9862	1.1124	1.2493	1.3936	1.5510
0.135	0.3846	0.4570	0.5362	0.6214	0.7139	0.8142	0.9224	1.0375	1.1647	1.2996	1.4444	1.6002
0.140	0.4292	0.5020	0.5804	0.6653	0.7582	0.8577	0.9649	1.0807	1.2056	1.3383	1.4818	1.6353
0.145	0.4663	0.5384	0.6160	0.7011	0.7938	0.8911	0.9963	1.1115	1.2340	1.3652	1.5064	1.6567
0.150	0.4959	0.5672	0.6444	0.7281	0.8182	0.9151	1.0197	1.1328	1.2518	1.3807	1.5188	1.6656
0.155	0.5184	0.5894	0.6647	0.7470	0.8349	0.9291	1.0323	1.1417	1.2589	1.3847	1.5193	1.6619
0.160	0.5338	0.6028	0.6778	0.7572	0.8432	0.9360	1.0356	1.1418	1.2557	1.3780	1.5109	1.6466
0.165	0.5430	0.6101	0.6823	0.7600	0.8434	0.9335	1.0304	1.1324	1.2427	1.3606	1.4861	1.6200
0.170	0.5459	0.6108	0.6804	0.7552	0.8362	0.9227	1.0152	1.1141	1.2203	1.3333	1.4538	1.5816
0.175	0.5458	0.6049	0.6717	0.7438	0.8209	0.9042	0.9992	1.0874	1.1888	1.2972	1.4115	1.5344
0.180	0.5334	0.5929	0.6566	0.7256	0.7993	0.8775	0.9624	1.0526	1.1490	1.2511	1.3602	1.4765
0.185	0.5188	0.5751	0.6313	0.7009	0.7709	0.8451	0.9247	1.0101	1.1009	1.1973	1.2998	1.4098
0.190	0.4991	0.5518	0.6091	0.6704	0.7371	0.8057	0.8806	0.9604	1.0456	1.1355	1.2320	1.3342
0.195	0.4746	0.5242	0.5774	0.6342	0.6950	0.7601	0.8297	0.9042	0.9829	1.0666	1.1561	1.2508
0.200	0.4456	0.4915	0.5387	0.5930	0.6491	0.7089	0.7732	0.8414	0.9150	0.9915	1.0732	1.1605
0.205	0.4128	0.4546	0.4995	0.5445	0.5981	0.6530	0.7112	0.7732	0.8393	0.9092	0.9848	1.0630
0.210	0.3762	0.4140	0.2022	0.4970	0.5391	0.5921	0.6445	0.7002	0.7593	0.8224	0.8892	0.9610
0.215	0.3365	0.3698	0.4052	0.4432	0.4834	0.5271	0.5735	0.6225	0.6773	0.7304	0.7893	0.8514
0.220	0.2938	0.3232	0.3533	0.3859	0.4213	0.4588	0.4984	0.5408	0.5861	0.6340	0.6851	0.7386
0.225	0.2499	0.2726	0.3065	0.3260	0.3557	0.3871	0.4205	0.4561	0.4936	0.5342	0.5766	0.6217
0.230	0.2018	0.2208	0.2412	0.2639	0.2876	0.3128	0.3397	0.3681	0.3988	0.4311	0.4651	0.5013
0.235	0.1525	0.1671	0.1827	0.1980	0.2175	0.2368	0.2565	0.2781	0.3011	0.3255	0.3513	0.3781
0.240	0.1025	0.1121	0.1226	0.1338	0.1451	0.1586	0.1719	0.1863	0.2017	0.2178	0.2350	0.2535
0.245	0.0515	0.0563	0.0615	0.0672	0.0732	0.0794	0.0865	0.0934	0.1013	0.1095	0.1178	0.1269
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.240	.245	.250	.255	.260	.265	.270	.275	.280	.285	.290	.295
0.000	-4.5676	-4.6513	-4.7267	-4.8126	-4.8936	-4.9728	-5.0506	-5.1268	-5.2046	-5.2781	-5.3497	-5.4215
0.005	-4.2008	-4.2656	-4.3181	-4.3878	-4.4452	-4.5010	-4.5529	-4.6025	-4.6522	-4.6926	-4.7324	-4.7688
0.010	-3.8361	-3.8827	-3.9248	-3.9624	-3.9997	-4.0318	-4.0581	-4.0819	-4.1000	-4.1127	-4.1198	-4.1209
0.015	-3.4758	-3.5033	-3.5265	-3.5456	-3.5592	-3.5679	-3.5703	-3.5672	-3.5569	-3.5380	-3.5145	-3.4806
0.020	-3.1228	-3.1274	-3.1338	-3.1328	-3.1250	-3.1109	-3.0894	-3.0603	-3.0224	-2.9759	-2.9196	-2.8514
0.025	-2.8244	-2.7605	-2.7482	-2.7267	-2.6991	-2.6626	-2.6177	-2.5638	-2.4971	-2.4242	-2.3362	-2.2358
0.030	-2.4966	-2.4025	-2.3705	-2.3301	-2.2827	-2.2246	-2.1571	-2.0786	-1.9887	-1.8856	-1.7682	-1.6375
0.035	-2.0932	-2.0522	-2.0026	-1.9443	-1.8770	-1.7988	-1.7092	-1.6079	-1.4988	-1.3640	-1.2192	-1.0590
0.040	-1.7682	-1.7109	-1.6456	-1.5701	-1.4833	-1.3863	-1.2761	-1.1578	-1.0129	-.8610	-.6892	-.4999
0.045	-1.4242	-1.3821	-1.3004	-1.2085	-1.1048	-.9885	-.8586	-.7146	-.5541	-.3773	-.1817	0.0347
0.050	-1.1420	-1.0603	-.9684	-.8611	-.7406	-.6069	-.4548	-.2946	-.1149	0.0843	0.3025	0.5426
0.055	-.8412	-.7498	-.6458	-.5276	-.3935	-.2433	-.0778	0.1098	0.3031	0.5223	0.7607	1.0243
0.060	-.6180	-.5001	-.3692	-.2253	-.0685	0.1013	0.2841	0.4818	0.6982	0.9352	1.1937	1.4764
0.065	-.3024	-.1828	-.0515	0.0931	0.2527	0.4290	0.6238	0.8378	1.0700	1.3230	1.5982	1.8982
0.070	0.0513	0.1895	0.3274	0.4699	0.6217	0.7874	0.9720	1.1801	1.4165	1.6835	1.9747	2.2893
0.075	0.1665	0.3044	0.4569	0.6250	0.8097	1.0120	1.2328	1.4732	1.7340	2.0164	2.3210	2.6489
0.080	0.3882	0.5407	0.7059	0.8847	1.0785	1.2886	1.5166	1.7640	2.0322	2.3226	2.6367	2.9761
0.085	0.5932	0.7504	0.9165	1.1111	1.4483	1.8448	2.1856	2.4648	2.7040	2.9246	3.1481	3.3958
0.090	0.7824	0.9469	1.1261	1.3040	1.5252	1.7657	2.0178	2.2841	2.5671	2.8697	3.1943	3.5437
0.095	0.9597	1.1261	1.3080	1.4984	1.7210	1.9579	2.2016	2.4647	2.7512	3.0618	3.3975	3.7589
0.100	1.1116	1.2884	1.4738	1.6764	2.6540	2.1317	2.3896	2.6656	2.8955	3.1717	3.4915	3.8526
0.105	1.2529	1.4291	1.6211	1.8286	2.0484	2.2816	2.5448	2.8200	3.1118	3.4257	3.7628	4.1244
0.110	1.3777	1.5566	1.7504	1.9585	2.1818	2.4215	2.6783	2.9543	3.2436	3.5654	3.9058	4.2671
0.115	1.4754	1.6665	1.8618	2.0719	2.2960	2.5354	2.7927	3.0575	3.3623	3.6769	4.0098	4.3692
0.120	1.5802	1.7611	1.9556	2.1656	2.3893	2.6283	2.8846	3.1590	3.4207	3.7633	4.0961	4.4529
0.125	1.6566	1.8363	2.0341	2.2402	2.4620	2.7013	2.9516	3.2259	3.5160	3.8214	4.1519	4.5031
0.130	1.7187	1.8994	2.0921	2.2985	2.5185	2.7535	3.0038	3.2715	3.5556	3.8589	4.1825	4.5222
0.135	1.7658	1.9443	2.1343	2.3390	2.5554	2.7868	3.0329	3.3088	3.5754	3.8723	4.1866	4.5175
0.140	1.7985	1.9749	2.1612	2.3619	2.5746	2.8013	3.0412	3.2948	3.5721	3.8615	4.1832	4.4933
0.145	1.8172	1.9903	2.1726	2.3690	2.5767	2.7980	3.0335	3.2833	3.5526	3.8294	4.1278	4.4415
0.150	1.8222	1.9915	2.1722	2.3603	2.5617	2.7755	3.0060	3.2478	3.5044	3.7769	4.0646	4.3693
0.155	1.8152	1.9781	2.1518	2.3359	2.5322	2.7408	2.9611	3.1930	3.4425	3.7046	3.9810	4.2733
0.160	1.7949	1.9522	2.1201	2.2981	2.4873	2.6875	2.9000	3.1292	3.3634	3.6147	3.8800	4.1595
0.165	1.7628	1.9151	2.0743	2.2469	2.4274	2.6201	2.8238	3.0388	3.2649	3.5061	3.7595	4.0267
0.170	1.7188	1.8639	2.0183	2.1815	2.3551	2.5384	2.7321	2.9374	3.1543	3.3809	3.6231	3.8763
0.175	1.6643	1.8025	1.9485	2.1053	2.2690	2.4423	2.6278	2.8210	3.0264	3.2426	3.4700	3.7095
0.180	1.5994	1.7303	1.8696	2.0141	2.1732	2.3361	2.5094	2.6932	2.8863	3.0891	3.3022	3.5274
0.185	1.5254	1.6487	1.7791	1.9170	2.0629	2.2175	2.2038	2.5514	2.7292	2.9225	3.1217	3.3314
0.190	1.4426	1.5575	1.6794	1.8077	1.9441	2.0875	2.2404	2.3989	2.5666	2.7429	2.9285	3.1239
0.195	1.3512	1.4578	1.5706	1.6871	1.8154	1.9484	2.0878	2.2361	2.3901	2.5521	2.7238	2.9026
0.200	1.2524	1.3502	1.4535	1.5634	1.6781	1.7994	1.9275	2.0641	2.2037	2.3525	2.5085	2.6769
0.205	1.1468	1.2355	1.3295	1.4280	1.5340	1.6428	1.7596	1.8805	2.0088	2.1431	2.2897	2.4310
0.210	1.0351	1.1146	1.1983	1.2866	1.3804	1.4791	1.5821	1.6912	1.8053	1.9226	2.0510	2.1824
0.215	0.9191	0.9878	1.0615	1.1395	1.2212	1.3080	1.3992	1.4949	1.5940	1.7003	1.8089	1.9257
0.220	0.7866	0.8593	0.9196	0.9865	1.0575	1.1319	1.2090	1.2937	1.3784	1.4694	1.5632	1.6605
0.225	0.6694	0.7192	0.7729	0.8292	0.8883	0.9509	1.0170	1.0830	1.1567	1.2436	1.3105	1.3939
0.230	0.5392	0.5802	0.6230	0.6678	0.7152	0.7656	0.8177	0.8735	0.9308	0.9909	1.0541	1.1205
0.235	0.4072	0.4375	0.4696	0.5041	0.5388	0.5768	0.6160	0.6573	0.7026	0.7466	0.7942	0.8437
0.240	0.2725	0.2930	0.3144	0.3366	0.3617	0.3859	0.4122	0.4401	0.4683	0.4990	0.5306	0.5648
0.245	0.1365	0.1467	0.1581	0.1690	0.1809	0.1948	0.2062	0.2203	0.2350	0.2499	0.2661	0.2823
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.300	.305	.310	.315	.320	.325	.330	.335	.340	.345	.350	.355
0.000	-5.4919	-5.5620	-5.6289	-5.6951	-5.7600	-5.8232	-5.8839	-5.9455	-6.0037	-6.0606	-6.1159	-6.1693
0.005	-4.8010	-4.8298	-4.8518	-4.8700	-4.8826	-4.8890	-4.8890	-4.8817	-4.8660	-4.8418	-4.8077	-4.7625
0.010	-4.1159	-4.1018	-4.0807	-4.0513	-4.0120	-3.9622	-3.9010	-3.8268	-3.7386	-3.6342	-3.5120	-3.3697
0.015	-3.4375	-3.3844	-3.3201	-3.2438	-3.1537	-3.0490	-2.9171	-2.7886	-2.6290	-2.4469	-2.2388	-2.0016
0.020	-2.7721	-2.6798	-2.5734	-2.4513	-2.3123	-2.1545	-1.9757	-1.7733	-1.5452	-1.2880	-.9981	-.6715
0.025	-2.1219	-1.9915	-1.8444	-1.6790	-1.4930	-1.2839	-1.0532	-.7877	-.4940	-.1662	0.2012	0.6125
0.030	-1.4892	-1.3232	-1.1373	-.9305	-.6996	-.4421	-.1558	0.1626	0.5171	0.9116	1.3511	1.8414
0.035	-.8779	-.6778	-.4558	-.2091	0.0639	0.3663	0.7012	1.0722	1.4819	1.9389	2.4445	3.0060
0.040	-.2901	-.0578	0.1986	0.4813	0.7935	1.1375	1.5172	1.9362	2.3986	2.9100	3.4752	4.0999
0.045	0.2778	0.5339	0.8220	1.1382	1.4859	1.8681	2.2884	2.7517	3.2592	3.8193	4.4365	5.1177
0.050	0.8016	1.0950	1.4115	1.7585	2.1385	2.5551	3.0115	3.5108	4.0652	4.6640	5.3266	6.0552
0.055	1.3106	1.6237	1.9660	2.3405	2.7488	3.1959	3.6842	4.2180	4.8021	5.4421	6.1412	6.9103
0.060	1.7833	2.1193	2.4841	2.8824	3.3163	3.7895	4.3044	4.8663	5.4794	6.1489	6.8802	7.6791
0.065	2.2239	2.5786	2.9638	3.3826	3.8376	4.3326	4.8708	5.4562	6.0931	6.7860	7.5408	8.3637
0.070	2.6304	3.0004	3.4042	3.8403	4.3135	4.8266	5.3826	5.9863	6.6413	7.3523	8.1244	8.9636
0.075	3.0041	3.3876	3.8049	4.2552	4.7427	5.2701	5.8387	6.4575	7.1256	7.8483	8.6315	9.4802
0.080	3.3423	3.7382	4.1653	4.6269	5.1249	5.6625	6.2432	6.8703	7.5462	8.2747	9.0645	9.9156
0.085	3.6894	4.0503	4.4856	4.9575	5.4614	6.0060	6.5924	7.2241	7.9039	8.6361	9.4242	10.2728
0.090	3.9205	4.3273	4.7668	5.2416	5.7519	6.2968	6.8891	7.5178	8.2015	8.9307	9.7141	10.5549
0.095	4.1470	4.5625	5.0063	5.4826	5.9970	6.5337	7.1341	7.7645	8.4397	9.1630	9.9378	10.7656
0.100	4.2524	4.6885	5.1583	5.6595	6.1895	6.7458	7.3298	7.9544	8.6221	9.3351	10.0965	10.9085
0.105	4.5121	4.9275	5.3723	5.8480	6.3563	6.8987	7.4770	8.0933	8.7508	9.4500	10.1953	10.9881
0.110	4.6530	5.0650	5.5051	5.9748	6.4760	7.0104	7.5798	8.1850	8.8267	9.5112	10.2376	11.0083
0.115	4.7598	5.1732	5.6091	6.0704	6.5599	7.0806	7.6351	8.2265	8.8562	9.5221	10.2270	10.9732
0.120	4.8322	5.2329	5.6578	6.1089	6.5883	7.0978	7.6397	8.2158	8.8281	9.4788	10.1672	10.8872
0.125	4.8729	5.2743	5.6866	6.1237	6.5915	7.0902	7.6203	8.1821	8.7760	9.4024	10.0617	10.7540
0.130	4.8868	5.2736	5.6824	6.1156	6.5744	7.0596	7.5722	8.1129	8.6829	9.2829	9.9140	10.5770
0.135	4.8746	5.2498	5.6500	6.0684	6.5412	7.0351	7.5412	8.0629	8.6036	9.1666	9.7555	10.3737
0.140	4.8315	5.2019	5.5862	5.9938	6.4230	6.8757	7.3522	7.8528	8.3780	8.9285	9.5047	10.1071
0.145	4.7750	5.1269	5.4996	5.8907	6.3026	6.7382	7.1945	7.6737	8.1763	8.7022	9.2514	9.8239
0.150	4.6891	5.0275	5.3860	5.7633	6.1686	6.5733	7.0034	7.4666	7.9467	8.4462	8.9667	9.5081
0.155	4.5829	4.9076	5.2491	5.6065	5.9869	6.3828	6.7982	7.3433	7.6886	8.0433	8.4784	8.9798
0.160	4.4539	4.7790	5.0908	5.4327	5.7926	6.1670	6.5621	6.9730	7.4018	7.9703	8.5328	9.0519
0.165	4.3063	4.6145	4.9170	5.2383	5.5776	5.9312	6.3052	6.6928	7.0968	7.5164	7.9528	8.4449
0.170	4.1418	4.4213	4.7145	5.0214	5.3430	5.6778	6.0275	6.3956	6.7702	7.1619	7.5702	7.9841
0.175	3.9596	4.2232	4.4992	4.7875	5.0893	5.4040	5.7315	6.0727	6.4261	6.7935	7.1759	7.5649
0.180	3.7626	4.0095	4.2679	4.5380	4.8198	5.1128	5.4190	5.7343	6.0673	6.4071	6.7582	7.1212
0.185	3.5516	3.7813	4.0219	4.2726	4.5346	4.8074	5.0914	5.3853	5.6855	6.0047	6.3300	6.6561
0.190	3.3263	3.5393	3.7619	3.9942	4.2404	4.4878	4.7449	5.0186	5.2999	5.5881	5.8872	6.1926
0.195	3.1026	3.2855	3.4893	3.7043	3.9246	4.1539	4.3940	4.6414	4.8971	5.1622	5.4337	5.7039
0.200	2.8423	3.0208	3.2059	3.4004	3.6026	3.8109	4.0270	4.2522	4.4836	4.7229	4.9683	5.2212
0.205	2.5842	2.7466	2.8760	3.0876	3.2709	3.4542	3.6549	3.8525	4.0582	4.2757	4.4999	4.7201
0.210	2.3189	2.4623	2.6115	2.7678	2.9272	3.0948	3.2674	3.4459	3.6287	3.8196	4.0139	4.2114
0.215	2.0423	2.1711	2.3010	2.4349	2.5780	2.7226	2.8749	3.0316	3.1908	3.3565	3.5264	3.6971
0.220	1.7654	1.8731	1.9852	2.1017	2.2217	2.3471	2.4770	2.6093	2.7459	2.8871	3.0329	3.1816
0.225	1.4800	1.5688	1.6629	1.7603	1.8590	1.9633	2.0721	2.1822	2.2964	2.4093	2.5407	2.6471
0.230	1.1899	1.2615	1.3360	1.4129	1.4941	1.6457	1.6628	1.7510	1.8468	1.9286	2.0330	2.1296
0.235	0.8952	0.9525	1.0060	1.0633	1.1235	1.1859	1.2503	1.3168	1.3849	1.4545	1.5280	1.5973
0.240	0.5984	0.6343	0.6709	0.7135	0.7505	0.7873	0.8348	0.8826	0.9250	0.9624	1.0208	1.0675
0.245	0.2993	0.3174	0.3365	0.3554	0.3756	0.3967	0.4179	0.4399	0.4622	0.4860	0.5103	0.5352
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

R (m) / Z (m)	.360	.365	.370	.375	.380	.385	.390	.395	.400	.405	.410	.415
0.000	-6.2211	-6.2711	-6.3191	-6.3654	-6.4097	-6.4522	-6.4927	-6.5312	-6.5678	-6.6024	-6.6348	-6.6653
0.005	-4.7051	-4.6334	-4.5460	-4.4403	-4.3135	-4.1624	-3.9828	-3.7693	-3.5159	-3.2142	-2.8538	-2.4212
0.010	-3.2046	-3.0136	-2.7930	-2.5382	-2.2440	-1.9037	-1.5092	-1.0507	-.5158	0.1114	0.8507	1.7281
0.015	-1.7330	-1.4268	-1.0777	-.6796	-.2248	0.2963	0.8950	1.5856	2.3858	3.3174	4.4088	5.6960
0.020	-.3029	0.1131	0.5837	1.1167	1.7221	2.4117	3.1998	4.1041	5.1462	6.3533	7.7596	9.4080
0.025	1.0742	1.5927	2.1757	2.8338	3.5771	4.4201	5.3791	6.4728	7.7314	9.1760	10.8516	12.8094
0.030	2.3886	3.000-	3.6864	4.4568	5.3237	6.3026	7.4113	8.6716	10.1081	11.7550	13.6509	15.8523
0.035	3.6310	4.3270	5.1043	5.9737	6.9473	8.0427	9.2778	10.6799	12.2601	14.0660	16.1310	18.5022
0.040	4.7931	5.5629	6.4189	7.3767	8.4381	9.6304	10.9686	12.4743	14.1978	16.0974	18.2819	20.7709
0.045	5.8702	6.7028	7.6256	8.6497	9.7888	11.0583	12.4735	14.0630	15.8435	17.8462	20.1041	22.6558
0.050	6.8576	7.7424	8.7192	9.7994	10.9956	12.3227	13.7975	15.4395	17.2707	19.3168	21.6063	24.1751
0.055	7.7523	8.6788	9.6976	10.8196	12.0571	13.4236	14.9344	16.6073	18.4629	20.5212	22.8087	25.3515
0.060	8.5536	9.5109	10.5600	11.7110	12.9752	14.3645	15.8913	17.5732	19.4300	21.4744	23.7289	26.2148
0.065	9.2606	10.2393	11.3085	12.4763	13.7531	15.1473	16.6785	18.3526	20.1860	22.1804	24.3924	26.7973
0.070	9.8754	10.8665	11.9433	13.1184	14.3959	15.7867	17.3016	18.9513	20.7471	22.7013	24.8256	27.1295
0.075	10.3988	11.3944	12.4698	13.6428	14.9103	16.2841	17.7727	19.3640	21.1302	23.0173	25.0517	27.2454
0.080	10.8346	11.8270	12.8918	14.0554	15.3039	16.6510	18.1028	19.6685	21.3528	23.1597	25.0993	27.1839
0.085	11.1859	12.1687	13.2259	14.3626	15.5848	16.8975	18.3045	19.8136	21.4283	23.1597	24.9903	26.9438
0.090	11.4569	12.4244	13.4615	14.5716	15.7605	17.0318	18.3926	19.8371	21.4016	23.0147	24.7487	26.5782
0.095	11.6515	12.5986	13.6113	14.6899	15.8408	17.0664	18.3748	19.7515	21.2159	22.7631	24.3915	26.1000
0.100	11.7746	12.6975	13.6798	14.7244	15.8334	17.0095	18.2551	19.5704	20.9545	22.4126	23.9377	25.5276
0.105	11.8310	12.7263	13.6761	14.6823	15.7473	16.8710	18.0560	19.3039	20.6114	21.9726	23.4017	24.8808
0.110	11.8252	12.6902	13.6048	14.5710	15.5893	16.6606	17.7854	18.9632	20.1927	21.4735	22.7985	24.1672
0.115	11.7619	12.5945	13.4720	14.3967	15.3671	16.3846	17.4487	18.5583	19.7114	20.9065	22.1436	23.4056
0.120	11.6457	12.4441	13.2845	14.1653	15.0877	16.0512	17.0543	18.0985	19.1768	20.2904	21.4361	22.6066
0.125	11.4805	12.2455	13.0459	13.8832	14.7524	15.6691	16.6109	17.5885	18.5754	19.6319	20.6952	21.7758
0.130	11.2727	12.0008	12.7617	13.5556	14.3818	15.2379	16.1244	17.0391	17.9804	18.9435	19.9253	20.9196
0.135	11.0245	11.7114	12.4352	13.1879	13.9649	14.7700	15.6015	16.4557	17.3315	18.2240	19.0259	20.0465
0.140	10.7363	11.3929	12.0760	12.7821	13.5139	14.2697	15.0460	15.8414	16.6563	17.4824	18.3200	19.1617
0.145	10.4196	11.0385	11.6806	12.3456	13.0319	13.7392	14.4641	15.2017	15.9578	16.7238	17.4953	18.2696
0.150	10.0704	10.6533	11.2568	11.8808	12.5244	13.1840	13.8581	14.5458	15.2437	15.9506	16.6607	17.3731
0.155	9.5335	10.1256	10.7420	11.3689	11.9922	12.6067	13.2330	13.8700	14.5194	15.1670	15.8161	16.4714
0.160	9.5411	10.0139	10.4838	10.9642	11.4685	12.0102	12.5912	13.1795	13.7757	14.3743	14.9683	15.5692
0.165	8.9364	9.4163	9.8934	10.3761	10.8732	11.3932	11.9358	12.4774	13.0272	13.5764	14.1263	14.6739
0.170	8.4129	8.8584	9.3185	9.7913	10.2747	10.7668	11.2656	11.7692	12.2743	12.7760	13.2766	13.7753
0.175	7.9715	8.3895	8.8160	9.2503	9.6915	10.1392	10.5925	11.0508	11.5120	11.9716	12.4301	12.8810
0.180	7.4966	7.8681	8.2500	8.6455	9.0522	9.4676	9.8892	10.3147	10.7415	11.1671	11.5869	11.9933
0.185	7.0070	7.3569	7.7209	8.0909	8.4632	8.8378	9.2148	9.5944	9.9765	10.3614	10.7438	11.1100
0.190	6.5032	6.8290	7.1592	7.4917	7.8294	8.1716	8.5167	8.8632	9.2094	9.5537	9.8952	10.2303
0.195	5.9941	6.2950	6.5872	6.8884	7.1971	7.4930	7.7781	8.0616	8.3524	8.6597	8.9924	9.3597
0.200	5.4766	5.7435	6.0091	6.2780	6.5607	6.8451	7.1269	7.4061	7.6821	7.9549	8.2239	8.4891
0.205	4.9519	5.1866	5.4253	5.6677	5.9131	6.1572	6.4036	6.6518	6.9000	7.1465	7.3894	7.6269
0.210	4.4185	4.6245	4.8348	5.0421	5.2749	5.4804	5.7168	5.9460	6.1576	6.3580	6.5537	6.7510
0.215	3.8774	4.0569	4.2416	4.4246	4.6158	4.8010	4.9903	5.1810	5.3702	5.5568	5.7395	5.9168
0.220	3.3324	3.4850	3.6422	3.7991	3.9588	4.1191	4.2826	4.4402	4.5798	4.7294	4.8905	5.0543
0.225	2.7797	2.9102	3.0335	3.1713	3.3009	3.4341	3.5651	3.6984	3.8289	3.9563	4.0809	4.2022
0.230	2.2313	2.3336	2.4365	2.5391	2.6568	2.7502	2.8524	2.9598	3.0556	3.1535	3.2540	3.3550
0.235	1.6748	1.7517	1.8285	1.9041	1.9882	2.0662	2.1417	2.2336	2.2994	2.3635	2.4279	2.4908
0.240	1.1178	1.1677	1.2115	1.2707	1.3237	1.3750	1.4277	1.4806	1.5286	1.5810	1.6247	1.6295
0.245	0.5591	0.5834	0.6102	0.6355	0.6616	0.6867	0.7137	0.7515	0.7718	0.7929	0.8068	0.8456
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.420	.425	.430	.435	440	.445	450	455	.460	.465	.470	.475
0.000	-6.6933	-6.7200	-6.7441	-6.7661	-6.7862	-6.8040	-6.8197	-6.8332	-6.8447	-6.8540	-6.8611	-6.8653
0.005	-1.8984	-1.2616	-.4782	0.4972	1.7293	3.3134	5.3928	8.1932	12.0852	17.7113	26.2641	40.1549
0.010	2.7763	4.0440	5.5888	7.4964	9.8859	12.9293	16.8820	22.1365	29.3171	39.4615	54.3808	77.4239
0.015	7.2256	9.0595	11.2800	13.9996	17.3735	21.6214	27.0604	34.1606	43.6189	56.6056	74.6812	101.4775
0.020	11.3551	13.6712	16.4535	19.8263	23.9673	29.0960	35.5513	43.8506	54.4443	68.4434	87.0491	111.9514
0.025	15.0920	17.7926	21.0051	24.8567	29.5187	35.2021	42.2093	50.9674	61.8551	75.5439	93.0223	114.5717
0.030	18.3952	21.3793	24.8913	29.0505	34.0075	39.9515	47.1214	55.7942	66.3391	79.0000	94.3960	112.4016
0.035	21.2370	24.4052	28.0919	32.4004	37.4560	43.4125	50.4428	58.7262	68.4752	79.8494	92.8639	107.3957
0.040	23.6160	26.8784	30.6302	34.9596	39.9496	45.7387	52.4138	60.0969	68.8632	78.7475	89.6634	101.3027
0.045	25.5456	28.8247	32.5572	36.7997	41.6256	47.1064	53.3057	60.2898	68.0251	76.5101	85.5603	94.8738
0.050	27.0564	30.2927	33.9283	38.0103	42.5842	47.6888	53.3566	59.5911	66.3670	73.5824	81.0679	88.5639
0.055	28.1789	31.3225	34.8141	38.6822	42.9558	47.6517	52.8067	58.3022	64.1799	70.3092	76.4980	82.4754
0.060	28.9547	31.9707	35.2810	38.9070	42.8730	47.1352	51.7296	56.5990	61.6735	66.8614	72.0119	76.9214
0.065	29.4248	32.2863	35.3979	38.7810	42.3888	46.2628	50.3404	54.6261	58.9124	63.4068	67.6961	72.3615
0.070	29.6263	32.3232	35.2245	38.3327	41.6318	45.1241	48.7634	52.4983	56.2848	60.0191	63.4956	66.9210
0.075	29.6023	32.1254	34.8168	37.6624	40.6687	43.7945	47.0174	50.2884	53.5609	56.7679	59.7692	62.5164
0.080	29.3867	31.7334	34.2183	36.8236	39.5414	42.3383	45.1948	48.0549	50.8558	53.6044	56.1668	58.4621
0.085	29.0104	31.1882	33.4692	35.8469	38.2941	40.8003	43.3299	45.8404	48.2895	50.6323	52.8026	54.7313
0.090	28.4961	30.5136	32.6045	34.7637	36.9787	39.2125	41.4373	43.6601	45.7931	47.8077	49.6593	51.2946
0.095	27.8834	29.7401	31.6495	33.6092	35.6033	37.6030	39.6854	41.5312	43.3915	45.1400	30.7177	48.1060
0.100	27.1780	28.8816	30.6303	32.4257	34.2019	35.9971	37.7550	39.4606	41.0901	42.5987	43.9638	45.1478
0.105	26.4026	27.9661	29.5624	31.1678	32.7894	34.3913	35.9592	37.4638	38.8908	40.2060	41.3808	42.4666
0.110	25.5720	27.0075	28.4621	29.9213	31.3778	32.8097	34.2045	35.5402	36.7880	37.9392	38.9663	39.8534
0.115	24.7002	26.0153	27.3380	28.6612	29.9734	31.2586	32.4950	33.6877	34.7801	35.7256	36.6804	37.4422
0.120	23.7970	24.9980	26.2049	27.4013	28.5856	29.7880	30.8465	31.8950	32.8708	33.7604	34.5225	35.1475
0.125	22.8676	23.9674	25.0664	26.1526	27.2176	28.2528	29.2505	30.1768	31.0310	31.8154	32.4943	33.0553
0.130	21.9225	22.9070	24.0568	24.9173	25.8538	26.8283	27.6912	28.5216	29.2848	29.9631	30.5509	31.0416
0.135	20.9684	21.8972	22.7956	23.6644	24.5534	25.3932	26.1888	26.9277	27.6044	28.2352	28.7732	29.2052
0.140	20.0075	20.8456	21.6738	22.4825	23.2676	24.0194	24.7315	25.3875	26.0765	26.5355	27.0114	27.3510
0.145	19.0426	19.8068	20.5605	21.2991	22.0051	22.6833	23.3216	23.9153	24.4436	24.9186	25.3327	25.6769
0.150	18.0783	18.7781	19.4622	20.1252	20.7690	21.3771	21.9524	22.4814	22.9585	23.3776	23.7346	24.0261
0.155	17.1181	17.7536	18.3758	18.9804	19.5593	20.1073	20.6180	21.0940	21.5218	21.8612	22.1593	22.4208
0.160	16.1601	16.7409	17.3048	17.8532	18.3756	18.8701	19.3334	19.7478	20.1336	20.4723	20.7558	20.9829
0.165	15.2100	15.7371	16.2534	16.7448	17.2138	17.6623	18.0780	18.4714	18.8117	19.0997	19.3386	19.5293
0.170	14.2654	14.7422	15.2070	15.6572	16.0803	16.4818	16.8539	17.1974	17.5208	17.8136	18.0597	18.2431
0.175	13.3350	13.7639	14.1812	14.5847	14.9668	15.3289	15.6627	15.9631	16.2184	16.4320	16.6123	16.7675
0.180	12.3968	12.7879	13.1690	13.5311	13.8762	14.1997	14.5005	14.7755	15.0211	15.2336	15.4094	15.5448
0.185	11.4765	11.8271	12.1681	12.4961	12.8111	13.2165	13.0407	12.5261	12.2183	12.5135	13.2115	13.9633
0.190	10.5526	10.8766	11.1341	11.4771	11.7492	12.0087	12.2394	12.4511	12.6452	12.8156	12.9561	13.0607
0.195	9.7178	9.9347	10.2067	10.4660	10.7169	10.9386	11.1387	11.3228	11.4897	11.6373	11.7639	11.8675
0.200	8.7493	9.0007	9.2413	9.4730	9.6958	9.8715	10.0371	10.2001	10.3545	10.4940	10.6123	10.7033
0.205	7.8571	8.0763	8.2821	8.4911	8.6804	8.8565	9.0207	9.1702	9.3018	9.4126	9.4996	9.5641
0.210	6.9564	7.1579	7.3410	7.5132	7.1049	6.6181	6.6930	7.2070	7.8470	8.2999	8.3949	8.4510
0.215	6.0877	6.2508	6.4071	6.5625	6.7085	6.8424	6.9633	7.0708	7.1643	7.2433	7.3070	7.3567
0.220	5.2121	5.3552	5.4803	5.6018	5.7206	5.8339	5.9394	6.0344	6.1165	6.1833	6.2351	6.2795
0.225	4.3196	4.4328	4.5413	4.6446	4.7424	4.8341	4.9192	4.9974	5.0682	5.1298	5.1749	5.2126
0.230	3.4551	3.5527	3.6466	3.7351	3.8171	3.8909	3.9551	4.0084	4.0493	4.0820	4.1227	4.1555
0.235	2.5526	2.6136	2.6742	2.7348	2.7959	2.8577	2.9207	2.9852	3.0420	3.0651	3.0878	3.1087
0.240	1.6426	1.6747	1.7207	1.7758	1.8349	1.8930	1.9454	1.9869	2.0157	2.0387	2.0552	2.0695
0.245	0.8822	0.9088	0.9279	0.9418	0.9533	0.9647	0.9785	0.9955	1.0079	1.0118	1.0270	1.0341
0.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields perpendicular to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.480	.485	.490	.495	.500
0.000	-6.8693	-6.8698	-6.9212	-6.9336	-6.9190
0.005	64.8361	114.6356	81.6790	90.7372	93.4512
0.010	114.9336	179.8744	157.4864	173.8986	178.7850
0.015	139.0602	195.2112	207.7045	228.0357	234.0414
0.020	144.9131	186.7317	219.5366	238.6331	244.1793
0.025	141.0810	170.9026	199.1708	213.3333	217.2967
0.030	132.5414	153.6412	169.4348	178.4247	180.7437
0.035	122.8129	138.0037	149.2357	155.6225	157.2219
0.040	113.1086	124.1297	132.5078	137.5984	139.1407
0.045	103.9802	112.2399	118.1615	121.4211	122.0659
0.050	95.6466	101.8641	106.3979	108.9957	109.5838
0.055	88.1157	92.9132	96.2628	98.0544	98.3094
0.060	81.3576	84.9311	87.4898	88.9563	89.2534
0.065	75.2947	77.5084	79.2994	80.4903	80.9042
0.070	69.8168	72.0654	73.6406	74.4993	74.5985
0.075	64.9332	66.8152	68.0938	68.7447	68.7434
0.080	60.4384	61.9471	62.9467	63.4315	63.3957
0.085	56.3361	57.5756	58.4207	58.8422	58.8107
0.090	52.6380	53.6581	54.3372	54.6574	54.6010
0.095	49.3377	46.5465	46.4741	47.9049	49.6230
0.100	46.1052	46.8179	47.2755	47.4676	47.3837
0.105	43.3319	43.9411	44.2990	44.4106	44.2809
0.110	40.5598	41.0713	41.3829	41.4895	41.3861
0.115	38.0284	38.4554	38.7158	38.8022	38.7070
0.120	35.6563	36.0398	36.2794	36.3567	36.2531
0.125	33.4943	33.8073	33.9901	34.0385	33.9486
0.130	31.4283	31.7045	31.8634	31.8983	31.7998
0.135	29.5314	29.7524	29.8684	29.8801	29.7846
0.140	27.5503	27.6856	27.8336	27.9797	27.8835
0.145	25.9436	26.1254	26.2146	26.2039	26.0933
0.150	24.2486	24.3987	24.4731	24.4676	24.3800
0.155	22.6330	22.7826	22.8568	22.8474	22.7637
0.160	21.1520	21.2618	21.3109	21.2963	21.2153
0.165	19.6728	19.7699	19.8215	19.8202	19.7416
0.170	18.3478	18.3800	18.4038	18.3901	18.3150
0.175	16.9058	17.0122	17.0260	17.0134	16.9503
0.180	15.6361	15.6862	15.7118	15.6926	15.6268
0.185	14.4197	14.4245	14.4234	14.4098	14.3535
0.190	13.1319	13.1861	13.1911	13.1689	13.1168
0.195	11.9418	11.9738	11.9804	11.9611	11.9150
0.200	10.7656	10.7960	10.7668	10.7846	10.7417
0.205	9.6167	9.6462	9.6518	9.6340	9.5957
0.210	8.5446	8.5220	8.5242	8.5116	8.4729
0.215	7.3931	7.4051	7.4167	7.4012	7.3700
0.220	6.3106	6.3202	6.3249	6.3125	6.2901
0.225	5.2688	5.2481	5.2532	5.2384	5.2169
0.230	4.1746	4.1776	4.1848	4.1770	4.1595
0.235	3.1399	3.1292	3.1310	3.1237	3.0963
0.240	2.0754	2.0828	2.0846	2.0725	2.0761
0.245	1.0381	1.0378	1.0404	1.0380	1.0352
0.250	0.0000	0.0000	0.0000	0.0000	0.0000

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.000	.005	.010	.015	.020	.025	.030	.035	.040	.045	.050	.055
0.000	51.0275	51.0293	51.0366	51.0466	51.0611	51.0829	51.1027	51.1300	51.1602	51.1967	51.2433	51.2873
0.005	51.2233	51.2251	51.2322	51.2423	51.2568	51.2778	51.2982	51.3254	51.3557	51.3920	51.4371	51.4810
0.010	51.4109	51.4127	51.4195	51.4297	51.4441	51.4640	51.4854	51.5124	51.5430	51.5788	51.6216	51.6656
0.015	51.5902	51.5921	51.5986	51.6088	51.6231	51.6420	51.6641	51.6909	51.7217	51.7571	51.7977	51.8416
0.020	51.7614	51.7634	51.7695	51.7796	51.7938	51.8121	51.8345	51.8610	51.8918	51.9267	51.9659	52.0095
0.025	51.9244	51.9265	51.9324	51.9425	51.9565	51.9746	51.9966	52.0229	52.0532	52.0878	52.1266	52.1696
0.030	52.0794	52.0814	52.0874	52.0973	52.1111	52.1289	52.1507	52.1766	52.2065	52.2406	52.2788	52.3212
0.035	52.2267	52.2285	52.2345	52.2441	52.2578	52.2753	52.2968	52.3222	52.3517	52.3852	52.4229	52.4647
0.040	52.3661	52.3679	52.3736	52.3832	52.3965	52.4138	52.4349	52.4599	52.4889	52.5217	52.5587	52.5996
0.045	52.4978	52.4997	52.5053	52.5147	52.5278	52.5447	52.5654	52.5898	52.6182	52.6504	52.6866	52.7268
0.050	52.6222	52.6239	52.6294	52.6386	52.6514	52.6679	52.6882	52.7121	52.7398	52.7714	52.8067	52.8460
0.055	52.7391	52.7409	52.7462	52.7552	52.7677	52.7838	52.8035	52.8270	52.8540	52.8847	52.9193	52.9576
0.060	52.8489	52.8507	52.8559	52.8646	52.8769	52.8925	52.9117	52.9346	52.9609	52.9908	53.0244	53.0616
0.065	52.9519	52.9535	52.9586	52.9671	52.9789	52.9942	53.0129	53.0350	53.0606	53.0896	53.1223	53.1584
0.070	53.0481	53.0496	53.0546	53.0627	53.0743	53.0890	53.1071	53.1286	53.1533	53.1816	53.2132	53.2482
0.075	53.1377	53.1392	53.1440	53.1519	53.1630	53.1773	53.1948	53.2152	53.2395	53.2667	53.2973	53.3312
0.080	53.2209	53.2225	53.2270	53.2347	53.2454	53.2592	53.2761	53.2960	53.3192	53.3455	53.3748	53.4075
0.085	53.2981	53.2996	53.3039	53.3113	53.3216	53.3350	53.3512	53.3704	53.3926	53.4178	53.4461	53.4775
0.090	53.3694	53.3708	53.3750	53.3821	53.3919	53.4050	53.4203	53.4387	53.4600	53.4842	53.5115	53.5414
0.095	53.4350	53.4363	53.4404	53.4472	53.4567	53.4689	53.4837	53.5013	53.5218	53.5449	53.5708	53.5995
0.100	53.4952	53.4965	53.5004	53.5068	53.5159	53.5275	53.5418	53.5586	53.5780	53.6001	53.6247	53.6521
0.105	53.5504	53.5515	53.5553	53.5614	53.5700	53.5810	53.5945	53.6106	53.6290	53.6500	53.6735	53.6994
0.110	53.6005	53.6017	53.6051	53.6110	53.6191	53.6296	53.6424	53.6576	53.6751	53.6950	53.7171	53.7418
0.115	53.6460	53.6471	53.6504	53.6559	53.6636	53.6736	53.6857	53.6999	53.7165	53.7352	53.7562	53.7793
0.120	53.6871	53.6881	53.6913	53.6964	53.7037	53.7131	53.7244	53.7380	53.7535	53.7711	53.7908	53.8126
0.125	53.7241	53.7251	53.7279	53.7329	53.7396	53.7484	53.7591	53.7717	53.7864	53.8028	53.8213	53.8416
0.130	53.7571	53.7580	53.7608	53.7653	53.7717	53.7799	53.7899	53.8010	53.8153	53.8307	53.8479	53.8669
0.135	53.7866	53.7874	53.7899	53.7942	53.8001	53.8078	53.8170	53.8279	53.8406	53.8549	53.8709	53.8885
0.140	53.8126	53.8134	53.8158	53.8196	53.8251	53.8322	53.8408	53.8510	53.8627	53.8758	53.8906	53.9068
0.145	53.8355	53.8362	53.8383	53.8420	53.8470	53.8536	53.8615	53.8709	53.8816	53.8937	53.9072	53.9221
0.150	53.8554	53.8561	53.8581	53.8614	53.8661	53.8720	53.8793	53.8879	53.8977	53.9088	53.9211	53.9347
0.155	53.8728	53.8734	53.8752	53.8782	53.8825	53.8879	53.8945	53.9023	53.9111	53.9213	53.9325	53.9448
0.160	53.8876	53.8882	53.8898	53.8926	53.8964	53.9013	53.9074	53.9144	53.9224	53.9315	53.9416	53.9526
0.165	53.9003	53.9008	53.9023	53.9048	53.9082	53.9126	53.9180	53.9243	53.9316	53.9397	53.9487	53.9585
0.170	53.9110	53.9114	53.9127	53.9149	53.9181	53.9220	53.9268	53.9325	53.9389	53.9461	53.9540	53.9627
0.175	53.9199	53.9202	53.9214	53.9234	53.9262	53.9297	53.9339	53.9388	53.9445	53.9508	53.9578	53.9653
0.180	53.9272	53.9275	53.9286	53.9303	53.9327	53.9358	53.9395	53.9438	53.9487	53.9542	53.9602	53.9667
0.185	53.9332	53.9335	53.9344	53.9358	53.9379	53.9406	53.9437	53.9475	53.9517	53.9564	53.9615	53.9670
0.190	53.9379	53.9381	53.9389	53.9402	53.9420	53.9442	53.9469	53.9500	53.9538	53.9576	53.9619	53.9665
0.195	53.9416	53.9418	53.9425	53.9436	53.9451	53.9469	53.9492	53.9518	53.9548	53.9580	53.9615	53.9652
0.200	53.9444	53.9446	53.9452	53.9461	53.9473	53.9488	53.9507	53.9528	53.9552	53.9578	53.9606	53.9635
0.205	53.9466	53.9467	53.9471	53.9479	53.9488	53.9501	53.9516	53.9533	53.9552	53.9572	53.9593	53.9614
0.210	53.9481	53.9482	53.9485	53.9491	53.9499	53.9509	53.9520	53.9533	53.9545	53.9562	53.9577	53.9591
0.215	53.9491	53.9492	53.9494	53.9499	53.9505	53.9512	53.9521	53.9530	53.9540	53.9550	53.9560	53.9568
0.220	53.9498	53.9498	53.9500	53.9504	53.9508	53.9513	53.9519	53.9526	53.9530	53.9537	53.9542	53.9546
0.225	53.9502	53.9502	53.9504	53.9506	53.9509	53.9512	53.9516	53.9520	53.9522	53.9525	53.9526	53.9525
0.230	53.9504	53.9505	53.9505	53.9507	53.9508	53.9510	53.9512	53.9514	53.9514	53.9513	53.9511	53.9507
0.235	53.9505	53.9506	53.9506	53.9506	53.9507	53.9508	53.9508	53.9507	53.9507	53.9504	53.9499	53.9492
0.240	53.9506	53.9506	53.9506	53.9506	53.9506	53.9506	53.9505	53.9503	53.9501	53.9496	53.9490	53.9480
0.245	53.9506	53.9506	53.9506	53.9506	53.9506	53.9505	53.9503	53.9501	53.9499	53.9492	53.9484	53.9473
0.250	53.9506	53.9506	53.9506	53.9506	53.9505	53.9504	53.9503	53.9500	53.9496	53.9483	53.9482	53.9471

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Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.060	.065	.070	.075	.080	.085	.090	.095	.100	.105	.110	.115
0.000	51.3322	51.3853	51.4495	51.5116	51.5766	51.6801	51.7266	51.8163	51.8999	51.9947	52.0893	52.1958
0.005	51.5267	51.5797	51.6351	51.7052	51.7701	51.8667	51.9184	52.0077	52.0883	52.1859	52.2737	52.3783
0.010	51.7123	51.7653	51.8214	51.8887	51.9542	52.0405	52.1008	52.1863	52.2666	52.3661	52.4491	52.5511
0.015	51.8892	51.9420	51.9988	52.0628	52.1291	52.2053	52.2743	52.3555	52.4373	52.5349	52.6187	52.7187
0.020	52.0574	52.1099	52.1668	52.2284	52.2947	52.3652	52.4398	52.5189	52.6027	52.6916	52.7859	52.8858
0.025	52.2170	52.2687	52.3250	52.3858	52.4513	52.5215	52.5967	52.6767	52.7618	52.8409	52.9479	53.0492
0.030	52.3680	52.4187	52.4744	52.5344	52.5989	52.6681	52.7421	52.8209	52.9048	52.9938	53.0880	53.1876
0.035	52.5105	52.5610	52.6152	52.6742	52.7377	52.8057	52.8784	52.9559	53.0384	53.1258	53.2185	53.3164
0.040	52.6447	52.6941	52.7476	52.8055	52.8678	52.9345	53.0059	53.0818	53.1627	53.2484	53.3391	53.4351
0.045	52.7709	52.8192	52.8717	52.9283	52.9893	53.0546	53.1244	53.1988	53.2778	53.3616	53.4504	53.5442
0.050	52.8892	52.9364	52.9877	53.0430	53.1025	53.1663	53.2345	53.3070	53.3842	53.4660	53.5525	53.6440
0.055	52.9997	53.0457	53.0956	53.1495	53.2076	53.2698	53.3361	53.4069	53.4819	53.5616	53.6457	53.7347
0.060	53.1026	53.1474	53.1960	53.2484	53.3048	53.3652	53.4297	53.4984	53.5713	53.6486	53.7302	53.8166
0.065	53.1982	53.2416	53.2888	53.3397	53.3943	53.4529	53.5154	53.5820	53.6526	53.7274	53.8065	53.8899
0.070	53.2867	53.3287	53.3743	53.4236	53.4764	53.5331	53.5935	53.6578	53.7260	53.7981	53.8746	53.9551
0.075	53.3683	53.4089	53.4529	53.5004	53.5514	53.6061	53.6643	53.7263	53.7919	53.8615	53.9349	54.0124
0.080	53.4433	53.4824	53.5248	53.5705	53.6196	53.6721	53.7281	53.7876	53.8507	53.9173	53.9879	54.0621
0.085	53.5119	53.5494	53.5901	53.6340	53.6811	53.7314	53.7851	53.8421	53.9025	53.9664	54.0336	54.1047
0.090	53.5744	53.6104	53.6493	53.6913	53.7363	53.7844	53.8357	53.8901	53.9478	54.0087	54.0729	54.1404
0.095	53.6310	53.6653	53.7025	53.7426	53.7855	53.8314	53.8802	53.9320	53.9868	54.0447	54.1057	54.1698
0.100	53.6821	53.7148	53.7501	53.7882	53.8290	53.8725	53.9190	53.9680	54.0200	54.0748	54.1325	54.1932
0.105	53.7278	53.7588	53.7924	53.8285	53.8671	53.9083	53.9521	53.9978	54.0476	54.0994	54.1537	54.2108
0.110	53.7686	53.7979	53.8297	53.8637	53.9001	53.9390	53.9803	54.0240	54.0701	54.1187	54.1698	54.2232
0.115	53.8048	53.8323	53.8621	53.8943	53.9285	53.9649	54.0036	54.0446	54.0878	54.1332	54.1809	54.2308
0.120	53.8364	53.8623	53.8902	53.9202	53.9523	53.9864	54.0225	54.0608	54.1010	54.1433	54.1876	54.2340
0.125	53.8639	53.8880	53.9142	53.9421	53.9720	54.0038	54.0374	54.0728	54.1102	54.1493	54.1902	54.2330
0.130	53.8875	53.9100	53.9346	53.9603	53.9879	54.0174	54.0484	54.0811	54.1156	54.1515	54.1891	54.2283
0.135	53.9077	53.9285	53.9508	53.9749	54.0004	54.0275	54.0560	54.0860	54.1175	54.1505	54.1848	54.2204
0.140	53.9246	53.9436	53.9642	53.9862	54.0097	54.0344	54.0606	54.0878	54.1165	54.1464	54.1774	54.2096
0.145	53.9383	53.9559	53.9747	53.9947	54.0161	54.0385	54.0622	54.0873	54.1129	54.1397	54.1675	54.1963
0.150	53.9495	53.9654	53.9652	54.0006	54.0199	54.0401	54.0614	54.0836	54.1067	54.1307	54.1553	54.1809
0.155	53.9581	53.9725	53.9878	54.0042	54.0214	54.0396	54.0585	54.0782	54.0987	54.1197	54.1414	54.1636
0.160	53.9646	53.9776	53.9912	54.0058	54.0210	54.0371	54.0537	54.0710	54.0889	54.1081	54.1259	54.1450
0.165	53.9691	53.9806	53.9927	54.0055	54.0189	54.0328	54.0474	54.0624	54.0777	54.0934	54.1093	54.1253
0.170	53.9720	53.9820	53.9926	54.0037	54.0154	54.0274	54.0398	54.0525	54.0654	54.0785	54.0917	54.1048
0.175	53.9735	53.9821	53.9912	54.0008	54.0107	54.0208	54.0312	54.0418	54.0525	54.0631	54.0736	54.0839
0.180	53.9737	53.9810	53.9888	53.9968	54.0050	54.0134	54.0219	54.0304	54.0389	54.0472	54.0552	54.0628
0.185	53.9729	53.9790	53.9855	53.9919	53.9987	54.0054	54.0121	54.0187	54.0250	54.0311	54.0368	54.0419
0.190	53.9713	53.9763	53.9814	53.9866	53.9919	53.9970	54.0021	54.0068	54.0112	54.0152	54.0186	54.0215
0.195	53.9691	53.9730	53.9770	53.9810	53.9850	53.9886	53.9920	53.9950	53.9977	53.9997	54.0011	54.0017
0.200	53.9664	53.9694	53.9723	53.9751	53.9778	53.9801	53.9820	53.9835	53.9845	53.9847	53.9842	53.9828
0.205	53.9635	53.9656	53.9675	53.9693	53.9708	53.9719	53.9725	53.9726	53.9720	53.9705	53.9683	53.9650
0.210	53.9605	53.9618	53.9628	53.9636	53.9640	53.9640	53.9634	53.9622	53.9602	53.9574	53.9536	53.9486
0.215	53.9576	53.9581	53.9583	53.9583	53.9577	53.9567	53.9551	53.9527	53.9495	53.9453	53.9402	53.9337
0.220	53.9547	53.9546	53.9542	53.9535	53.9520	53.9501	53.9476	53.9445	53.9399	53.9346	53.9283	53.9205
0.225	53.9522	53.9515	53.9505	53.9491	53.9470	53.9444	53.9410	53.9368	53.9316	53.7848	53.9179	53.9090
0.230	53.9499	53.9488	53.9474	53.9454	53.9428	53.9395	53.9355	53.9306	53.9246	53.9176	53.9092	53.8994
0.235	53.9481	53.9467	53.9448	53.9424	53.9394	53.9357	53.9311	53.9256	53.9191	53.9114	53.9024	53.8919
0.240	53.9468	53.9451	53.9430	53.9402	53.9370	53.9330	53.9279	53.9221	53.9151	53.9070	53.8975	53.8866
0.245	53.9459	53.9441	53.9419	53.9389	53.9355	53.9312	53.9260	53.9195	53.9127	53.9043	53.8945	53.8833
0.250	53.9457	53.9438	53.9415	53.9385	53.9350	53.9306	53.9254	53.9192	53.9119	53.9034	53.8935	53.8822

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

R (m) / Z (m)	.120	.125	.130	.135	.140	.145	.150	.155	.160	.165	.170	.175
0.000	52.3077	52.4253	52.5505	52.6781	52.8269	52.9687	53.1183	53.2808	53.4474	53.6229	53.8084	54.0023
0.005	52.4901	52.6080	52.7332	52.8607	53.0140	53.1552	53.3061	53.4680	53.6326	53.8075	53.9920	54.1839
0.010	52.6624	52.7798	52.9043	53.0323	53.1816	53.3229	53.4823	53.6385	53.8043	53.9778	54.1604	54.3541
0.015	52.8283	52.9440	53.0665	53.1943	53.3348	53.4759	53.6319	53.7869	53.9526	54.1258	54.3159	54.5044
0.020	52.9917	53.1038	53.2224	53.3479	53.4805	53.6206	53.7683	53.9241	54.0882	54.2608	54.4424	54.6332
0.025	53.1515	53.2601	53.3751	53.4970	53.6259	53.7622	53.9062	54.0581	54.2184	54.3872	54.5650	54.7519
0.030	53.2930	53.4040	53.5214	53.6440	53.7701	53.9003	54.0356	54.1771	54.3258	54.4827	54.6488	54.8252
0.035	53.4199	53.5287	53.6435	53.7642	53.8911	54.0245	54.1595	54.2962	54.4361	54.5808	54.7321	54.8914
0.040	53.5364	53.6431	53.7555	53.8736	53.9979	54.1282	54.2653	54.4088	54.5593	54.7163	54.8802	55.0516
0.045	53.6432	53.7475	53.8573	53.9728	54.0939	54.2212	54.3547	54.4947	54.6410	54.7952	54.9558	55.1241
0.050	53.7402	53.8421	53.9490	54.0614	54.1795	54.3035	54.4332	54.5693	54.7118	54.8609	55.0172	55.1807
0.055	53.8285	53.9272	54.0312	54.1403	54.2548	54.3751	54.5010	54.6330	54.7716	54.9156	55.0667	55.2248
0.060	53.9075	54.0032	54.1039	54.2109	54.3205	54.4368	54.5585	54.6861	54.8195	54.9590	55.1049	55.2585
0.065	53.9778	54.0704	54.1676	54.2696	54.3767	54.4888	54.6063	54.7297	54.8576	54.9918	55.1321	55.2786
0.070	54.0399	54.1290	54.2226	54.3209	54.4239	54.5317	54.6446	54.7625	54.8857	55.0145	55.1489	55.2892
0.075	54.0938	54.1794	54.2694	54.3636	54.4625	54.5658	54.6738	54.7867	54.9046	55.0275	55.1559	55.2895
0.080	54.1402	54.2222	54.3082	54.3984	54.4927	54.5915	54.6946	54.8022	54.9145	55.0315	55.1535	55.2807
0.085	54.1793	54.2575	54.3396	54.4257	54.5153	54.6092	54.7073	54.8095	54.9160	55.0270	55.1424	55.2625
0.090	54.2114	54.2859	54.3639	54.4455	54.5307	54.6196	54.7125	54.8091	54.9097	55.0144	55.1233	55.2363
0.095	54.2371	54.3077	54.3815	54.4586	54.5392	54.6231	54.7105	54.8015	54.8963	54.9946	55.0967	55.2026
0.100	54.2567	54.3233	54.3932	54.4654	54.5412	54.6201	54.7021	54.7874	54.8760	54.9676	55.0631	55.1618
0.105	54.2706	54.3331	54.3985	54.4661	54.5374	54.6112	54.6877	54.7672	54.8496	54.9350	55.0233	55.1147
0.110	54.2787	54.3377	54.3987	54.4621	54.5282	54.5967	54.6678	54.7414	54.8177	54.8965	54.9778	55.0618
0.115	54.2829	54.3374	54.3940	54.4529	54.5139	54.5773	54.6429	54.7108	54.7807	54.8529	54.9274	55.0040
0.120	54.2822	54.3326	54.3848	54.4391	54.4953	54.5535	54.6136	54.6755	54.7394	54.8050	54.8725	54.9418
0.125	54.2775	54.3237	54.3717	54.4213	54.4727	54.5257	54.5802	54.6364	54.6942	54.7533	54.8139	54.8759
0.130	54.2691	54.3112	54.3549	54.4001	54.4466	54.4944	54.5437	54.5941	54.6456	54.6983	54.7520	54.8068
0.135	54.2574	54.2957	54.3351	54.3757	54.4174	54.4604	54.5040	54.5487	54.5944	54.6407	54.6877	54.7354
0.140	54.2429	54.2771	54.3127	54.3486	54.3857	54.4235	54.4620	54.5012	54.5409	54.5810	54.6213	54.6619
0.145	54.2259	54.2564	54.2876	54.3197	54.3518	54.3847	54.4193	54.4518	54.4857	54.5197	54.5536	54.5874
0.150	54.2069	54.2336	54.2608	54.2884	54.3168	54.3445	54.3728	54.4011	54.4274	54.4573	54.4850	54.5121
0.155	54.1862	54.2093	54.2326	54.2560	54.2796	54.3036	54.3265	54.3496	54.3724	54.3942	54.4160	54.4367
0.160	54.1636	54.1838	54.2032	54.2227	54.2420	54.2611	54.2805	54.2977	54.3153	54.3319	54.3474	54.3618
0.165	54.1413	54.1572	54.1732	54.1888	54.2040	54.2187	54.2329	54.2460	54.2581	54.2695	54.2795	54.2880
0.170	54.1177	54.1304	54.1427	54.1547	54.1660	54.1765	54.1862	54.1949	54.2022	54.2082	54.2127	54.2154
0.175	54.0939	54.1034	54.1123	54.1208	54.1283	54.1350	54.1404	54.1445	54.1473	54.1483	54.1477	54.1449
0.180	54.0700	54.0765	54.0824	54.0873	54.0914	54.0942	54.0957	54.0957	54.0939	54.0904	54.0846	54.0767
0.185	54.0465	54.0501	54.0530	54.0548	54.0554	54.0547	54.0524	54.0484	54.0426	54.0346	54.0243	54.0114
0.190	54.0235	54.0245	54.0246	54.0234	54.0209	54.0168	54.0110	54.0033	53.9936	53.9814	53.9656	53.9492
0.195	54.0014	53.9999	53.9974	53.9934	53.9878	53.9827	53.9717	53.9606	53.9471	53.9311	53.9124	53.8906
0.200	53.9803	53.9767	53.9717	53.9651	53.9569	53.9469	53.9350	53.9205	53.9038	53.8841	53.8617	53.8360
0.205	53.9606	53.9549	53.9477	53.9387	53.9281	53.9154	53.9006	53.8834	53.8635	53.8408	53.8149	53.7857
0.210	53.9424	53.9348	53.9256	53.9146	53.9017	53.8868	53.8693	53.8495	53.8268	53.8012	53.7723	53.7400
0.215	53.9259	53.9166	53.9056	53.8929	53.8779	53.8608	53.8412	53.8191	53.7939	53.7657	53.7341	53.6988
0.220	53.9111	53.9005	53.8880	53.8735	53.8569	53.8380	53.8165	53.7922	53.7650	53.7346	53.7006	53.6631
0.225	53.8986	53.8866	53.8728	53.8569	53.8389	53.8184	53.7952	53.7692	53.7402	53.7079	53.6719	53.6320
0.230	53.8881	53.8750	53.8602	53.8432	53.8239	53.8021	53.7776	53.7502	53.7196	53.6861	53.6481	53.6065
0.235	53.8799	53.8660	53.8503	53.8324	53.8122	53.7894	53.7638	53.7353	53.7037	53.6685	53.6295	53.5865
0.240	53.8739	53.8595	53.8430	53.8246	53.8031	53.7802	53.7549	53.7247	53.6921	53.6559	53.6161	53.5722
0.245	53.8704	53.8556	53.8388	53.8199	53.7985	53.7746	53.7480	53.7183	53.6852	53.6485	53.6081	53.5636
0.250	53.8693	53.8543	53.8374	53.8177	53.7968	53.7729	53.7460	53.7161	53.6828	53.6460	53.6054	53.5608

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.180	.185	.190	.195	.200	.205	.210	.215	.220	.225	.230	.235
0.000	54.2046	54.4174	54.6408	54.8782	55.1178	55.3555	55.6470	55.9263	56.2180	56.5331	56.8578	57.2005
0.005	54.3862	54.5986	54.8197	55.0580	55.2952	55.5510	55.8218	56.0998	56.3943	56.7033	57.0270	57.3687
0.010	54.5521	54.7631	54.9828	55.2131	55.4553	55.7087	55.9731	56.2526	56.5455	56.8520	57.1729	57.5102
0.015	54.7026	54.9114	55.1301	55.3577	55.5966	55.8477	56.1123	56.3860	56.6745	56.9781	57.2953	57.6293
0.020	54.8334	55.0435	55.2591	55.4742	55.7209	55.9676	56.2267	56.5349	56.7841	57.0819	57.3956	57.7240
0.025	54.9483	55.1544	55.3707	55.5957	55.8262	56.0707	56.3253	56.5931	56.8717	57.1653	57.4750	57.7957
0.030	55.0129	55.2128	55.4261	55.6538	55.8958	56.1479	56.4050	56.6674	56.9462	57.2290	57.5289	57.7934
0.035	55.0603	55.2406	55.4338	55.6415	55.8654	56.1069	56.3679	56.6497	56.9542	57.2705	57.5641	57.8715
0.040	55.2309	55.4186	55.6153	55.8215	56.0378	56.2647	56.5027	56.7523	57.0141	57.2885	57.5762	57.8767
0.045	55.3000	55.4799	55.6644	55.8560	56.0568	56.2692	56.4954	56.7377	56.9985	57.2800	57.5845	57.9062
0.050	55.3516	55.5299	55.7166	55.9128	56.1189	56.3348	56.5607	56.7967	57.0428	57.2992	57.5658	57.8428
0.055	55.3900	55.5625	55.7429	55.9317	56.1278	56.3331	56.5471	56.7702	57.0030	57.2462	57.5004	57.7663
0.060	55.4165	55.5825	55.7561	55.9372	56.1262	56.3235	56.5295	56.7435	56.9659	57.1975	57.4390	57.6913
0.065	55.4314	55.5908	55.7601	55.9306	56.1115	56.3003	56.4969	56.7018	56.9154	57.1380	57.3694	57.6102
0.070	55.4353	55.5877	55.7466	55.9121	56.0846	56.2643	56.4513	56.6413	56.8489	57.0602	57.2787	57.5070
0.075	55.4289	55.5740	55.7251	55.8824	56.0461	56.2163	56.3935	56.5776	56.7692	56.9680	57.1753	57.3904
0.080	55.4128	55.5503	55.6946	55.8421	55.9968	56.1574	56.3237	56.4976	56.6775	56.8643	57.0582	57.2594
0.085	55.3875	55.5174	55.6521	55.7920	55.9374	56.0882	56.2446	56.4067	56.5749	56.7490	56.9295	57.1164
0.090	55.3538	55.4756	55.6021	55.7331	55.8670	56.0096	56.1553	56.3059	56.4622	56.6236	56.7903	56.9626
0.095	55.3124	55.4258	55.5439	55.6661	55.7922	55.9224	56.0574	56.1968	56.3405	56.4887	56.6421	56.7998
0.100	55.2639	55.3695	55.4787	55.5915	55.7076	55.8282	55.9520	56.0797	56.2111	56.3465	56.4856	56.6330
0.105	55.2089	55.3064	55.4068	55.5104	55.6170	55.7268	55.8391	55.9557	56.0748	56.1968	56.3222	56.4505
0.110	55.1484	55.2375	55.3292	55.4235	55.5203	55.6197	55.7215	55.8260	55.9315	56.0417	56.1532	56.2666
0.115	55.0827	55.1636	55.2465	55.3315	55.4186	55.5075	55.5984	55.6911	55.7855	55.8817	55.9793	56.0783
0.120	55.0128	55.0853	55.1595	55.2354	55.3127	55.3913	55.4714	55.5520	55.6347	55.7180	55.8019	55.8866
0.125	54.9390	55.0035	55.0691	55.1358	55.2034	55.2719	55.3412	55.4109	55.4811	55.5516	55.6222	55.6926
0.130	54.8624	54.9189	54.9760	55.0334	55.0917	55.1500	55.2086	55.2672	55.3257	55.3835	55.4409	55.4974
0.135	54.7833	54.8318	54.8805	54.9294	54.9780	55.0266	55.0746	55.1224	55.1691	55.2150	55.2593	55.3022
0.140	54.7026	54.7432	54.7837	54.8239	54.8637	54.9023	54.9403	54.9771	55.0125	55.0464	55.0783	55.1084
0.145	54.6208	54.6539	54.6863	54.7179	54.7484	54.7780	54.8062	54.8325	54.8569	54.8792	54.8989	54.9158
0.150	54.5385	54.5642	54.5888	54.6122	54.6341	54.6544	54.6729	54.6897	54.7029	54.7140	54.7218	54.7263
0.155	54.4563	54.4755	54.4919	54.5072	54.5208	54.5325	54.5414	54.5479	54.5514	54.5516	54.5481	54.5407
0.160	54.3749	54.3864	54.3961	54.4039	54.4093	54.4123	54.4124	54.4094	54.4032	54.3930	54.3802	54.3598
0.165	54.2947	54.2995	54.3021	54.3025	54.3003	54.2950	54.2865	54.2746	54.2587	54.2387	54.2140	54.1842
0.170	54.2161	54.2145	54.2105	54.2037	54.1941	54.1811	54.1645	54.1440	54.1191	54.0893	54.0550	54.0149
0.175	54.1393	54.1321	54.1218	54.1084	54.0914	54.0711	54.0457	54.0181	53.9847	53.9461	53.9023	53.8523
0.180	54.0662	54.0527	54.0364	54.0166	53.9931	53.9655	53.9341	53.8976	53.8561	53.8092	53.7565	53.6974
0.185	53.9957	53.9769	53.9556	53.9290	53.8992	53.8653	53.8268	53.7830	53.7340	53.6793	53.6183	53.5505
0.190	53.9287	53.9050	53.8775	53.8461	53.8103	53.7704	53.7254	53.6751	53.6188	53.5567	53.4880	53.4122
0.195	53.8657	53.8372	53.8049	53.7682	53.7273	53.6815	53.6304	53.5739	53.5114	53.4423	53.3665	53.2832
0.200	53.8070	53.7741	53.7363	53.6959	53.6499	53.5989	53.5424	53.4800	53.4113	53.3366	53.2540	53.1639
0.205	53.7529	53.7161	53.6750	53.6280	53.5789	53.5230	53.4616	53.3941	53.3201	53.2393	53.1512	53.0548
0.210	53.7036	53.6633	53.4891	53.5690	53.5124	53.4542	53.3884	53.3161	53.2374	53.1513	53.0577	52.9566
0.215	53.6595	53.6160	53.5680	53.5151	53.4569	53.3929	53.3229	53.2467	53.1629	53.0730	52.9747	52.8682
0.220	53.6209	53.5744	53.5237	53.4678	53.4064	53.3391	53.2658	53.1858	53.0991	53.0045	52.9022	52.7915
0.225	53.5884	53.5392	53.4838	53.4275	53.3633	53.2933	53.2171	53.1341	53.0441	52.9463	52.8405	52.7262
0.230	53.5605	53.5101	53.4547	53.3941	53.3278	53.2555	53.1769	53.0914	52.9987	52.8982	52.7896	52.6724
0.235	53.5392	53.4873	53.4303	53.3681	53.3000	53.2259	53.1454	53.0581	52.9632	52.8607	52.7500	52.6304
0.240	53.5240	53.4709	53.4128	53.3493	53.2798	53.2048	53.1229	53.0340	52.9379	52.8338	52.7215	52.6005
0.245	53.5147	53.4610	53.4022	53.3380	53.2681	53.1921	53.1095	53.0197	52.9225	52.8176	52.7044	52.5821
0.250	53.5116	53.4579	53.3987	53.3342	53.2641	53.1878	53.1049	53.0153	52.9174	52.8123	52.6987	52.5761

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.240	.245	.250	.255	.260	.265	.270	.275	.280	.285	.290	.295
0.000	57.5588	57.9347	58.3407	58.7495	59.1858	59.6465	60.1321	60.6446	61.1800	61.7509	62.3556	62.9919
0.005	57.7244	58.0989	58.5078	58.9074	59.3436	59.8015	60.2857	60.7952	61.3263	61.8990	62.4982	63.1307
0.010	57.8647	58.2357	58.6273	59.0410	59.4703	59.9243	60.4054	60.9085	61.4403	62.0022	62.5953	63.2218
0.015	57.9787	58.3465	58.7327	59.1381	59.5653	60.0139	60.4873	60.9847	61.5099	62.0672	62.6482	63.2662
0.020	58.0641	58.4336	58.8107	59.2096	59.6297	60.0709	60.5358	61.0247	61.5409	62.0842	62.6566	63.2641
0.025	58.1331	58.4877	58.8617	59.2525	59.6641	60.0964	60.5369	61.0298	61.5338	62.0640	62.6256	63.2166
0.030	58.0725	58.5223	58.8863	59.2693	59.6686	60.0910	60.5339	61.0003	61.4904	62.0077	62.5538	63.1255
0.035	58.1928	58.5305	58.8853	59.2571	59.6460	60.0555	60.4858	60.9373	61.4001	61.9126	62.4393	62.9907
0.040	58.1886	58.5173	58.8596	59.2193	59.5974	59.9917	60.4070	60.8321	61.3046	61.7815	62.2896	62.8215
0.045	58.2075	58.4792	58.8106	59.1571	59.5201	59.9010	60.3002	60.7186	61.1587	61.6191	62.1031	62.6131
0.050	58.1302	58.4281	58.738	59.0706	59.4193	59.7840	60.1740	60.5673	60.9843	61.4247	61.8847	62.3678
0.055	58.0445	58.3357	58.6405	58.9596	59.2936	59.6417	60.0057	60.3989	60.7834	61.2005	61.6335	62.0933
0.060	57.9552	58.2314	58.5207	58.8240	59.1419	59.4753	59.8233	60.1816	60.5562	60.9488	61.3581	61.7875
0.065	57.8610	58.1225	58.3954	58.6805	58.9785	59.2900	59.6157	59.9554	60.3071	60.6738	61.0553	61.4544
0.070	57.7451	57.9934	58.2520	58.5213	58.8015	59.0927	59.3953	59.7095	60.0355	60.3750	60.7316	61.0983
0.075	57.6140	57.8456	58.0856	58.3345	58.5932	58.8622	59.1424	59.4343	59.7387	60.0563	60.3857	60.7220
0.080	57.4681	57.6844	57.9090	58.1419	58.3834	58.6336	58.8926	59.1607	59.4380	59.7246	60.0208	60.3266
0.085	57.3098	57.5101	57.7174	57.9315	58.1515	58.3790	58.6154	58.8607	59.1143	59.3757	59.6444	59.9197
0.090	57.1408	57.3245	57.5144	57.7104	57.9119	58.1200	58.3347	58.5558	58.7829	59.0158	59.2540	59.4974
0.095	56.9621	57.1296	57.3014	57.4784	57.6606	57.8470	58.0386	58.2354	58.4369	58.6425	58.8515	59.0633
0.100	56.7755	56.9261	57.0808	57.2390	57.3775	57.5654	57.7351	57.9072	58.0849	58.2652	58.4475	58.6311
0.105	56.5818	56.7149	56.8528	56.9924	57.1345	57.2793	57.4256	57.5739	57.7214	57.8751	58.0309	58.1861
0.110	56.3824	56.5001	56.6195	56.7406	56.8631	56.9867	57.1114	57.2364	57.3618	57.4866	57.6106	57.7330
0.115	56.1792	56.2799	56.3821	56.4849	56.5880	56.6913	56.7943	56.8969	56.9973	57.0966	57.1938	57.2877
0.120	55.9715	56.0568	56.1420	56.2269	56.3111	56.3941	56.4759	56.5557	56.6254	56.7075	56.7779	56.8440
0.125	55.7627	55.8321	55.9004	55.9677	56.0335	56.0970	56.1584	56.2159	56.2702	56.3205	56.3655	56.4054
0.130	55.5528	55.6069	55.6592	55.7090	55.7564	55.8008	55.8419	55.8791	55.9109	55.9376	55.9582	55.9718
0.135	55.3433	55.3822	55.4185	55.4521	55.4817	55.5077	55.5292	55.5447	55.5563	55.5605	55.5576	55.5466
0.140	55.1352	55.1594	55.1803	55.1974	55.2103	55.2184	55.2212	55.2184	55.2081	55.1907	55.1642	55.1305
0.145	54.9296	54.9394	54.9455	54.9469	54.9435	54.9345	54.9191	54.8971	54.8672	54.8296	54.7824	54.7253
0.150	54.7272	54.7234	54.7149	54.7016	54.6824	54.6570	54.6244	54.5842	54.5358	54.4784	54.4108	54.3324
0.155	54.5288	54.5123	54.4903	54.4623	54.4279	54.3865	54.3378	54.2808	54.2143	54.1381	54.0509	53.9528
0.160	54.3359	54.3066	54.2716	54.2300	54.1814	54.1251	54.0602	53.9867	53.9038	53.8100	53.7048	53.5875
0.165	54.1490	54.1077	54.0600	54.0055	53.9434	53.8729	53.7935	53.7047	53.6048	53.4951	53.3728	53.2374
0.170	53.9688	53.9163	53.8568	53.7898	53.7147	53.6309	53.5377	53.4342	53.3199	53.1943	53.0557	52.9037
0.175	53.7960	53.7329	53.6623	53.5835	53.4964	53.3991	53.2936	53.1769	53.0483	52.9079	52.7545	52.5874
0.180	53.6308	53.5581	53.4770	53.3879	53.2887	53.1807	53.0622	52.9325	52.7914	52.6373	52.4701	52.2883
0.185	53.4755	53.3928	53.3019	53.2023	53.0934	52.9739	52.8728	52.7029	52.5469	52.3828	52.2028	52.0079
0.190	53.3291	53.2376	53.1377	53.0286	52.9096	52.7804	52.6403	52.4879	52.3232	52.1453	51.9534	51.7472
0.195	53.1923	53.0932	52.9846	52.8673	52.7389	52.6003	52.4505	52.2889	52.1134	51.9251	51.7223	51.5043
0.200	53.0659	52.9591	52.8432	52.7175	52.5816	52.4345	52.2756	52.1044	51.9206	51.7227	51.5100	51.2809
0.205	52.9504	52.8369	52.7141	52.5812	52.4385	52.2832	52.1164	51.9371	51.7447	51.5383	51.3182	51.0800
0.210	52.8460	52.7266	52.5976	52.4583	52.3083	52.1467	51.9731	51.7867	51.5865	51.3730	51.1433	50.8986
0.215	52.7538	52.6283	52.4940	52.3490	52.1933	52.0256	51.8456	51.6529	51.4467	51.2254	50.9888	50.7376
0.220	52.6739	52.5419	52.4035	52.2538	52.0927	51.9201	51.7342	51.5360	51.3243	51.0977	50.8557	50.5983
0.225	52.6027	52.4700	52.3265	52.1726	52.0073	51.8303	51.6404	51.4368	51.2205	50.9936	50.7425	50.4794
0.230	52.5460	52.4097	52.2634	52.1059	51.9373	51.7564	51.5629	51.3565	51.1354	50.9001	50.6490	50.3821
0.235	52.5015	52.3629	52.2139	52.0542	51.8828	51.6991	51.5026	51.2928	51.0694	50.8305	50.5766	50.3063
0.240	52.4696	52.3294	52.1786	52.0168	51.8436	51.6579	51.4594	51.2476	51.0216	50.7808	50.5246	50.2521
0.245	52.4505	52.3092	52.1571	51.9943	51.8199	51.6335	51.4335	51.2204	50.9931	50.7510	50.4934	50.2196
0.250	52.4442	52.3022	52.1503	51.9868	51.8119	51.6249	51.4247	51.2113	50.9836	50.7410	50.4832	50.2089

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.300	.305	.310	.315	.320	.325	.330	.335	.340	.345	.350	.355
0.000	63.6653	64.3755	65.1335	65.9363	66.7889	67.6966	68.6673	69.6938	70.7975	71.9779	73.2432	74.6031
0.005	63.8003	64.5072	65.2624	66.0605	66.9088	67.8115	68.7730	69.7986	70.8966	72.0705	73.3286	74.6806
0.010	63.8828	64.5877	65.3327	66.1218	66.9609	67.8539	68.8047	69.8189	70.9017	72.0605	73.3022	74.6357
0.015	63.9197	64.6110	65.3437	66.1205	66.9464	67.8238	68.7992	69.7527	70.8149	71.9503	73.1666	74.4743
0.020	63.9042	64.5816	65.2992	66.0597	66.8666	67.7230	68.6342	69.6048	70.6393	71.7438	72.9248	74.1893
0.025	63.8409	64.5014	65.1999	65.9391	66.7229	67.5570	68.4383	69.3778	70.3780	71.4438	72.5818	73.7987
0.030	63.7319	64.3718	65.0485	65.7624	66.5189	67.3219	68.1727	69.0754	70.0353	71.0563	72.1438	73.3038
0.035	63.5779	64.1942	64.8446	65.5326	66.2592	67.0272	67.8407	68.7027	69.6107	70.5876	71.6187	72.7140
0.040	63.3819	63.9735	64.5963	65.2517	65.9447	66.6756	67.4483	68.2650	69.1286	70.0445	71.0140	72.0379
0.045	63.1632	63.7102	64.3028	64.9244	65.5803	66.2708	66.9990	67.7704	68.5770	69.4324	70.3330	71.2857
0.050	62.8622	63.4075	63.9663	64.5536	65.1698	65.8184	66.4995	67.2095	67.9786	68.7599	69.5920	70.4660
0.055	62.5700	63.0694	63.5934	64.1435	64.7177	65.3220	65.9543	66.6162	67.3103	68.0413	68.7928	69.5958
0.060	62.2328	62.7022	63.1885	63.6990	64.2319	64.7903	65.3690	65.9751	66.6066	67.2672	67.9533	68.6653
0.065	61.8690	62.3025	62.7527	63.2224	63.7107	64.2202	64.7493	65.2995	65.8711	66.4610	67.0724	67.7064
0.070	61.4785	61.8729	62.2909	62.7192	63.1642	63.6249	64.1003	64.5932	65.1017	65.6257	66.1647	66.7166
0.075	61.0710	61.4285	61.8070	62.1935	62.5940	63.0069	63.4216	63.8657	64.3125	64.7688	65.2308	65.7073
0.080	60.6423	60.9681	61.3033	61.6493	62.0035	62.3658	62.7394	63.1231	63.5062	63.8944	64.2913	64.6868
0.085	60.2011	60.4881	60.7845	61.0972	61.4004	61.7162	62.0362	62.3615	62.6871	63.0148	63.3391	63.6636
0.090	59.7456	59.9983	60.2552	60.5185	60.7859	61.0381	61.3253	61.5698	61.8661	62.1287	62.3884	62.6401
0.095	59.2773	59.4927	59.7090	59.9342	60.1627	60.3218	60.6086	60.8272	61.0393	61.2462	61.4491	61.6244
0.100	58.8153	58.9993	59.1826	59.3643	59.5439	59.7205	59.8932	60.0602	60.2206	60.3678	60.5032	60.6242
0.105	58.3399	58.4913	58.6393	58.7829	58.9213	59.0533	59.1782	59.2967	59.4102	59.5023	59.5824	59.6420
0.110	57.8529	57.9695	58.0821	58.1899	58.2922	58.3882	58.4771	58.5526	58.6014	58.6502	58.6767	58.6812
0.115	57.3778	57.4597	57.5330	57.5983	57.6561	57.7072	57.7523	57.7919	57.8212	57.8208	57.7934	57.7457
0.120	56.9048	56.9408	56.9525	56.9466	56.9298	56.9087	56.8901	56.8806	56.8870	56.9159	56.9366	56.8397
0.125	56.4376	56.4623	56.4785	56.4833	56.4752	56.4532	56.4164	56.3638	56.2944	56.2072	56.1013	55.9684
0.130	55.9773	55.9740	55.9604	55.9353	55.8979	55.8463	55.7783	55.6918	55.5845	55.4542	55.2986	55.1157
0.135	55.5262	55.4958	55.4540	55.3996	55.3302	55.2410	55.1309	54.9997	54.8473	54.6736	54.4787	54.2623
0.140	55.0860	55.0295	54.9609	54.8789	54.7816	54.6675	54.5356	54.3837	54.2095	54.0106	53.7848	53.5296
0.145	54.6572	54.5768	54.4831	54.3746	54.2496	54.1082	53.9473	53.7651	53.5599	53.3294	53.0717	52.7845
0.150	54.2421	54.1383	54.0213	53.8882	53.7477	53.5704	53.3816	53.1734	52.9409	52.6836	52.3993	52.0853
0.155	53.8414	53.7166	53.5769	53.4200	53.2475	53.0553	52.8429	52.6039	52.3497	52.0697	51.7593	51.4172
0.160	53.4567	53.3217	53.1509	52.9737	52.7785	52.5614	52.3281	52.0703	51.7886	51.4772	51.1388	50.7729
0.165	53.0885	52.9234	52.7439	52.5469	52.3313	52.0965	51.8394	51.5605	51.2571	50.9285	50.5723	50.1856
0.170	52.7376	52.5560	52.3582	52.1422	51.9078	51.6534	51.3775	51.0798	50.7564	50.4081	50.0320	49.6285
0.175	52.4052	52.2072	51.9926	51.7599	51.5081	51.2363	50.9427	50.6263	50.2855	49.9199	49.5269	49.1055
0.180	52.0917	51.8793	51.6484	51.4004	51.1328	50.8446	50.5352	50.2028	49.8462	49.4644	49.0556	48.6190
0.185	51.7976	51.5709	51.3269	51.0640	50.7822	50.4796	50.1553	49.8084	49.4375	49.0410	48.6183	48.1688
0.190	51.5236	51.2844	51.0275	50.7519	50.4562	50.1410	49.8037	49.4432	49.0590	48.6501	48.2151	47.7527
0.195	51.2685	51.0196	50.7506	50.4635	50.1565	49.8289	49.4796	49.1075	48.7118	48.2914	47.8450	47.3729
0.200	51.0380	50.7769	50.4977	50.1997	49.8821	49.5436	49.1837	48.8013	48.3951	47.9647	47.5087	47.0265
0.205	50.8264	50.5563	50.2509	49.9604	49.6329	49.2841	48.9164	48.5241	48.1098	47.6697	47.2067	46.7147
0.210	50.6371	50.3584	50.0617	49.7461	49.4104	49.0541	48.6769	48.2768	47.8535	47.4068	46.9347	46.4373
0.215	50.4701	50.1835	49.8794	49.5570	49.2138	48.8505	48.4653	48.0588	47.6287	47.1750	46.6964	46.1930
0.220	50.3233	50.0315	49.7214	49.3921	49.0432	48.6736	48.2826	47.8696	47.4341	46.9744	46.4907	45.9818
0.225	50.1998	49.9026	49.5872	49.2529	48.8989	48.5234	48.1280	47.7100	47.2691	46.8036	46.3171	45.8054
0.230	50.0983	49.7971	49.4774	49.1389	48.7805	48.4236	48.0013	47.5795	47.1349	46.6677	46.1750	45.6585
0.235	50.0193	49.7160	49.3920	49.0500	48.6882	48.3062	47.9031	47.4778	47.0301	46.5594	46.0645	45.5464
0.240	49.9630	49.6560	49.3309	48.9863	48.6228	48.2368	47.8326	47.4063	46.9554	46.4845	45.9866	45.4650
0.245	49.9289	49.6208	49.2942	48.9484	48.5831	48.1976	47.7906	47.3617	46.9110	46.4367	45.9389	45.4175
0.250	49.9178	49.6089	49.2819	48.9360	48.5701	48.1837	47.7765	47.3476	46.8955	46.4214	45.9233	45.4008

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.360	.365	.370	.375	.380	.385	.390	.395	.400	.405	.410	.415
0.000	76.0666	77.6455	79.3545	81.2061	83.2202	85.4170	87.8210	90.4659	93.3739	96.5990	100.1917	104.2133
0.005	76.1356	77.7055	79.4032	81.2433	83.2437	85.4246	87.8104	90.4357	93.3169	96.5117	100.0690	104.0465
0.010	76.0694	77.6158	79.2860	81.0950	83.0592	85.1981	87.5352	90.0960	92.9139	96.0267	99.4813	103.3319
0.015	75.8716	77.3786	79.0069	80.7667	82.6733	84.7457	87.0042	89.4728	92.1803	95.1613	98.4522	102.1049
0.020	75.5463	77.0036	78.5738	80.2661	82.0966	84.0800	86.2337	88.5796	91.1403	93.9443	97.0233	100.4162
0.025	75.0998	76.4967	77.9943	79.6058	81.3428	83.2165	85.2442	87.4407	89.8248	92.4190	95.2455	98.3275
0.030	74.5420	75.8653	77.2817	78.8018	80.4278	82.1779	84.0598	86.0871	88.2669	90.6248	93.1678	95.9346
0.035	73.8813	75.1227	76.4494	77.8630	79.3682	80.9803	82.7021	84.5552	86.5125	88.6144	90.8585	93.2486
0.040	73.1261	74.2806	75.5059	76.8168	78.1872	79.6508	81.2052	82.8522	84.6481	86.4365	88.3747	90.4058
0.045	72.2909	73.3524	74.4724	75.6547	76.9002	78.2139	79.7115	81.0427	82.5583	84.1367	85.7722	87.4524
0.050	71.3853	72.3495	73.3623	74.4223	75.5326	76.6904	77.8964	79.1476	80.4368	81.7595	83.1017	84.4529
0.055	70.4174	71.2871	72.1882	73.1267	74.0990	75.1043	76.1381	77.1940	78.2689	79.3519	80.4140	81.4516
0.060	69.4072	70.1730	70.9667	71.7831	72.6221	73.4766	74.3404	75.2110	76.0803	76.9276	77.7390	78.4942
0.065	68.3567	69.0251	69.7112	70.4095	71.1147	71.8216	72.5329	73.2274	73.8991	74.5171	75.1118	75.6124
0.070	67.2823	67.8529	68.4294	69.0148	69.5949	70.1688	70.7238	71.2538	71.7467	72.1859	72.5555	72.8288
0.075	66.1849	66.6641	67.1359	67.6145	68.0789	68.5186	68.9333	69.2825	69.6411	69.9055	70.0855	70.1632
0.080	65.0820	65.4711	65.8439	66.2200	66.5682	66.8897	67.1739	67.4154	67.5963	67.7012	67.7187	67.6350
0.085	63.9770	64.2811	64.5700	64.8396	65.0843	65.2921	65.4572	65.5698	65.6184	65.5936	65.4629	65.2233
0.090	62.8786	63.1029	63.3059	63.4860	63.6274	63.7336	63.7935	63.7911	63.5314	63.5673	63.3204	62.9578
0.095	61.7930	61.9399	62.0636	62.1534	62.2107	62.2203	62.1877	62.0814	61.9036	61.6506	61.2960	60.8291
0.100	60.7233	60.8009	60.8488	60.8622	60.8372	60.7647	60.6369	60.4462	60.1799	59.8327	59.3878	58.8322
0.105	59.6778	59.6880	59.6682	59.6104	59.5095	59.3612	59.1551	58.8859	58.5424	58.1119	57.5942	56.9700
0.110	58.6588	58.6085	58.5256	58.4023	58.2349	58.0174	57.7425	57.4033	56.9900	56.4980	55.9131	55.2283
0.115	57.6695	57.5629	57.4212	57.2389	57.0119	56.7334	56.3978	55.9997	55.5263	54.9762	54.3423	53.6072
0.120	56.7155	56.5559	56.3604	56.1249	55.8431	55.5111	55.1211	54.6697	54.1480	53.5514	52.8702	52.1000
0.125	55.7880	55.5848	55.3431	55.0593	54.7259	54.3229	53.9130	53.4152	52.8386	52.2276	51.4996	50.6979
0.130	54.9029	54.6561	54.3700	54.0457	53.6719	53.2467	52.7715	52.2358	51.6353	50.9656	50.2214	49.3977
0.135	54.0244	53.7650	53.4654	53.0770	52.6680	52.2095	51.6967	51.1208	50.4956	49.7992	48.9854	48.1930
0.140	53.2428	52.9221	52.5638	52.1624	51.7180	51.2262	50.6878	50.0832	49.4320	48.7132	47.9283	47.0731
0.145	52.4658	52.1134	51.7252	51.2977	50.8244	50.3055	49.7370	49.1125	48.4407	47.6972	46.9034	46.0393
0.150	51.7392	51.3582	50.9398	50.4814	49.9810	49.4380	48.8467	48.2053	47.5157	46.7618	45.9516	45.0836
0.155	51.0422	50.6332	50.1888	49.7081	49.1896	48.6291	48.0161	47.3579	46.6504	45.8890	45.0717	44.2007
0.160	50.3772	49.9492	49.4866	48.9872	48.4484	47.8680	47.2434	46.5715	45.8506	45.0812	44.2568	43.3854
0.165	49.7786	49.3471	48.8822	48.3747	47.8157	47.1960	46.5230	45.8396	45.1084	44.3342	43.5086	42.6323
0.170	49.1971	48.7353	48.2403	47.7091	47.1387	46.5263	45.8689	45.1636	44.4156	43.6447	42.8211	41.9472
0.175	48.6542	48.1712	47.6551	47.1045	46.5183	45.8952	45.2340	44.5334	43.7931	43.0115	42.1802	41.3178
0.180	48.1534	47.6568	47.1279	46.5656	45.9688	45.3364	44.6672	43.9602	43.2142	42.4281	41.6016	40.7367
0.185	47.6893	47.1800	46.6400	46.0672	45.4607	44.8197	44.1438	43.4320	42.6838	41.8986	41.0747	40.2099
0.190	47.2627	46.7424	46.1922	45.6103	44.9984	44.3552	43.6784	42.9656	42.2145	41.4225	40.5915	39.7345
0.195	46.8719	46.3422	45.7832	45.1934	44.5727	43.9149	43.2205	42.4923	41.7331	40.9457	40.1327	39.2970
0.200	46.5162	45.9792	45.4126	44.8165	44.1896	43.5315	42.8418	42.1203	41.3668	40.5808	39.7622	38.9107
0.205	46.1976	45.6526	45.0796	44.4776	43.8453	43.1845	42.4940	41.7730	41.0209	40.2375	39.4223	38.5748
0.210	45.9137	45.3622	44.7836	44.1763	43.5404	42.8757	42.1810	41.4585	40.7078	39.9278	39.1170	38.2744
0.215	45.6633	45.1072	44.5242	43.9130	43.2737	42.6062	41.9101	41.1840	40.4280	39.6431	38.8303	37.9906
0.220	45.4476	44.8871	44.2998	43.6857	43.0434	42.3739	41.6771	40.9504	40.1973	39.4077	38.5846	37.7359
0.225	45.2659	44.7018	44.1096	43.4944	42.8500	42.1786	41.4801	40.7537	40.0002	39.2168	38.4042	37.5639
0.230	45.1172	44.5511	43.9574	43.3384	42.6950	42.0201	41.3202	40.5936	39.8409	39.0592	38.2544	37.4279
0.235	45.0021	44.4331	43.8381	43.2172	42.5697	41.8964	41.1964	40.4700	39.7167	38.9366	38.1257	37.2855
0.240	44.9202	44.3489	43.7519	43.1311	42.4828	41.8085	41.1084	40.3815	39.6286	38.8503	38.0466	37.2197
0.245	44.8702	44.2993	43.7022	43.0792	42.4307	41.7564	41.0556	40.3298	39.5767	38.7982	37.9950	37.1671
0.250	44.8547	44.2824	43.6851	43.0613	42.4136	41.7388	41.0379	40.3112	39.5582	38.7809	37.9772	37.1502

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.420	.425	.430	.435	.440	.445	.450	.455	.460	.465	.470	.475
0.000	108.7388	113.8829	119.7608	126.5454	134.4620	143.8140	155.0284	168.7120	185.7940	207.7135	236.7624	277.3167
0.005	108.5213	113.5917	119.3808	126.0493	133.8099	142.9461	153.8552	167.0963	183.4895	204.2827	231.4596	268.3394
0.010	107.6648	112.5219	118.0544	124.3869	131.6933	140.2091	150.2400	162.1974	176.6401	194.3256	216.2608	243.6813
0.015	106.1759	110.7349	115.8673	121.6772	128.2944	135.8736	144.6066	154.7177	166.4162	180.0780	195.3208	213.0668
0.020	104.1577	108.3222	112.9452	118.0964	123.8690	130.2964	137.4887	145.6137	154.2131	163.4959	172.7159	180.5315
0.025	101.6997	105.4034	109.4301	113.8482	118.6663	123.8898	129.4888	135.3668	141.3025	146.8773	151.2462	152.6615
0.030	98.8752	102.0649	105.4886	109.1435	113.0091	117.0354	121.1276	125.0890	128.6594	131.1899	132.2198	130.2798
0.035	95.7854	98.4644	101.2721	104.1799	107.1362	110.0627	112.7919	115.1827	116.8472	117.3455	115.9890	111.9720
0.040	92.5202	94.7009	96.9170	99.1303	101.2501	103.2149	104.8388	105.9193	106.1564	105.1674	102.4629	97.4531
0.045	89.1609	90.8678	92.5457	94.1257	95.5350	96.6686	97.3712	97.4733	96.6820	94.7372	91.2620	85.8942
0.050	85.7811	87.0588	88.2414	89.2697	90.0679	90.5200	90.5087	89.8635	88.3892	85.8495	82.0067	76.6434
0.055	82.4331	83.3228	84.0757	84.6296	84.9148	84.8355	84.3049	83.1094	81.1737	78.3098	74.3429	69.1329
0.060	79.1639	79.7126	80.0935	80.2538	80.1396	79.6277	78.6682	77.1349	74.9114	71.8882	67.9612	63.0493
0.065	76.0071	76.2579	76.3283	76.1779	75.7080	74.8943	73.6296	71.8645	69.4334	66.4204	62.6089	58.2100
0.070	72.9827	72.9837	72.7942	72.3705	71.6549	70.6065	69.1514	67.2230	64.7757	61.7428	58.0566	53.8146
0.075	70.1109	69.9008	69.4997	68.8625	67.9605	66.7337	65.1401	63.1352	60.6759	57.7316	54.2633	50.2884
0.080	67.4003	67.0125	66.4401	65.6432	64.5922	63.2423	61.5711	59.5514	57.0863	54.2493	50.9839	47.2975
0.085	64.8507	64.3213	63.6090	62.6881	61.5285	60.1039	58.3849	56.3449	53.9662	51.2405	48.1614	44.7417
0.090	62.4593	61.8175	60.9941	59.9816	58.7222	57.2729	55.5314	53.5231	51.2183	48.6134	45.7181	42.5413
0.095	60.2329	59.4903	58.5904	57.5053	56.2235	54.7226	53.0292	51.0185	48.7900	46.3150	40.1933	40.6319
0.100	58.1566	57.3425	56.3775	55.2533	53.9299	52.4239	50.7109	48.7848	46.6492	44.2870	41.7228	38.9654
0.105	56.2262	55.3545	54.3438	53.1744	51.8460	50.3467	48.6636	46.7930	44.7379	42.4971	40.0812	37.5111
0.110	54.4329	53.5208	52.4747	51.2890	49.9565	48.4687	46.8211	45.0122	43.0377	40.9098	38.6303	36.2149
0.115	52.7762	51.8255	50.7571	49.5625	48.2358	46.7698	45.1602	43.4134	41.5196	39.4831	37.3399	35.0731
0.120	51.2329	50.2617	49.1811	47.9849	46.6691	45.2440	43.6640	41.9730	40.1565	38.2316	36.1892	34.0491
0.125	49.8083	48.8193	47.7358	46.5426	45.2423	43.8311	42.3115	40.6777	38.9374	37.0967	35.1621	33.1432
0.130	48.4908	47.4866	46.4521	45.2243	43.9358	42.5680	41.0831	39.5074	37.8378	36.0785	34.2352	32.3193
0.135	47.2727	46.2760	45.1869	44.0370	42.7513	41.4075	39.9713	38.4492	36.8477	35.1658	33.4101	31.5916
0.140	46.1477	45.1467	44.0681	42.9105	41.6735	40.3563	38.9617	37.4896	35.9583	34.3360	32.6637	30.9055
0.145	45.1094	44.1104	43.0408	41.8994	40.6852	39.4004	38.0443	36.6218	35.1339	33.5869	31.9888	30.3462
0.150	44.1500	43.1577	42.0983	40.9705	39.7838	38.5274	37.2100	35.8273	34.3966	32.9120	31.3770	29.8000
0.155	43.2714	42.2812	41.2346	40.1258	38.9586	37.7325	36.4511	35.1147	33.7314	32.2949	30.8169	29.3059
0.160	42.4590	41.4780	40.4415	39.3518	38.2054	37.0092	35.7606	34.4649	33.1232	31.7390	30.3182	28.8668
0.165	41.7128	40.7396	39.7165	38.6429	37.5200	36.3490	35.1342	33.8392	32.5740	31.2668	29.9016	28.4935
0.170	41.0276	40.0644	39.0536	37.9964	36.8938	35.7503	34.5547	33.3369	32.0946	30.8216	29.5139	28.1675
0.175	40.4061	39.4400	38.4480	37.4066	36.3261	35.2029	34.0453	32.8491	31.6161	30.3526	29.0655	27.7615
0.180	39.8312	38.8833	37.8966	36.8723	35.8092	34.7094	33.5734	32.4078	31.2154	29.9974	28.7552	27.4902
0.185	39.3087	38.3709	37.3978	36.3876	35.3413	34.2729	33.1500	31.9861	30.8104	29.6435	28.4710	27.2699
0.190	38.8348	37.9058	37.0672	35.9491	34.9249	33.8583	32.7685	31.6573	30.5201	29.3591	28.1763	26.9737
0.195	38.4243	37.4784	36.5375	35.5540	34.5386	33.4940	32.4221	31.3298	30.2179	29.0853	27.9307	26.7532
0.200	38.0275	37.1167	36.1743	35.1999	34.1872	33.1707	32.1290	31.0573	29.9599	28.8411	27.7051	26.5563
0.205	37.6946	36.7831	35.8471	34.8878	33.8989	32.8836	31.8452	30.7862	29.7089	28.6158	27.5093	26.3902
0.210	37.3986	36.4920	35.5657	34.6105	33.6144	32.5908	31.5565	30.5150	29.4668	28.4122	27.3396	26.2357
0.215	37.1248	36.2339	35.3169	34.3690	33.3982	32.4078	31.3985	30.3715	29.3275	28.2675	27.1924	26.1061
0.220	36.8690	35.9915	35.1004	34.1656	33.2047	32.2250	31.2270	30.2113	29.1784	28.1287	27.0651	25.9973
0.225	36.6977	35.8072	34.8942	33.9602	33.0071	32.0364	31.0499	30.0492	29.0360	28.0087	26.9584	25.9048
0.230	36.5794	35.7084	34.8143	33.8968	32.9553	31.9895	30.9988	29.9828	28.9410	27.8886	26.8680	25.8252
0.235	36.4188	35.5287	34.6181	33.6900	32.7473	31.7929	30.8300	29.8614	28.8758	27.8390	26.8066	25.7674
0.240	36.3689	35.4945	34.5977	33.6794	32.7407	31.7825	30.8059	29.8118	28.8035	27.7878	26.7601	25.7263
0.245	36.3135	35.4357	34.5358	33.6157	32.6778	31.7239	30.7563	29.7748	28.7708	27.7476	26.7353	25.7008
0.250	36.2987	35.4232	34.5254	33.6071	32.6698	31.7153	30.7451	29.7600	28.7590	27.7466	26.7243	25.6948

Magnetic Fields parallel to the z-axis of the Helmholtz Coil

Z (m) \ R (m)	.480	.485	.490	.495	.500
0.000	336.9410	432.6698	215.6760	135.2975	35.1293
0.005	320.7858	399.5061	211.3425	132.7310	34.9478
0.010	277.1225	314.3533	198.3044	125.0304	34.3929
0.015	227.4641	235.3712	176.5783	112.2174	33.4834
0.020	183.9628	177.5385	146.1804	94.3134	32.2384
0.025	149.6591	137.9933	111.7390	74.1121	30.8423
0.030	123.7369	110.9010	89.3772	61.2458	29.8350
0.035	104.2727	92.0116	74.2844	52.5167	28.7644
0.040	89.5782	78.4081	63.6154	46.2232	27.6119
0.045	78.3275	68.4053	56.1143	42.1410	27.3514
0.050	69.5820	60.8025	50.3635	38.7669	26.6303
0.055	62.6725	54.9238	46.0138	36.3092	26.2280
0.060	57.1348	50.1879	42.4292	34.1485	25.6357
0.065	52.6327	46.2893	39.4751	32.3641	25.1301
0.070	48.9192	43.4259	37.4859	31.2600	24.9090
0.075	45.8358	40.9267	35.6655	30.1789	24.5937
0.080	43.2253	38.7959	34.0939	29.2193	24.2721
0.085	40.9908	36.9673	32.7435	28.3918	23.9846
0.090	39.0958	35.4311	31.6063	27.6805	23.7128
0.095	37.4745	33.3465	29.7308	26.4200	23.2066
0.100	36.0274	32.9438	29.7553	26.5022	23.2251
0.105	34.7917	31.9493	29.0174	26.0293	23.0184
0.110	33.6763	31.0388	28.3300	25.5777	22.8095
0.115	32.6998	30.2446	27.7305	25.1803	22.6172
0.120	31.8258	29.5355	27.1958	24.8243	22.4388
0.125	31.0533	28.9066	26.7174	24.4998	22.2680
0.130	30.3441	28.3226	26.2678	24.1930	22.1106
0.135	29.7219	27.8127	25.8755	23.9221	21.9642
0.140	29.0852	27.2501	25.4470	23.6763	21.8265
0.145	28.6659	26.9541	25.2176	23.4626	21.7004
0.150	28.1893	26.5533	24.9003	23.2383	21.5746
0.155	27.7676	26.2080	24.6327	23.0486	21.4646
0.160	27.3907	25.8961	24.3890	22.8745	21.3584
0.165	27.0575	25.6086	24.1619	22.7210	21.2634
0.170	26.7785	25.3587	23.9604	22.5659	21.1698
0.175	26.4476	25.1222	23.7708	22.4298	21.0862
0.180	26.2037	24.9029	23.6079	22.3071	21.0057
0.185	26.0169	24.7194	23.4596	22.1939	20.9361
0.190	25.7589	24.5474	23.3186	22.0918	20.8701
0.195	25.5623	24.3873	23.1933	22.0004	20.8115
0.200	25.4028	24.2458	23.0558	21.9199	20.7567
0.205	25.2578	24.1225	22.9822	21.8441	20.7087
0.210	25.1708	24.0153	22.8978	21.7822	20.6646
0.215	25.0164	23.9138	22.8193	21.7227	20.6271
0.220	24.9235	23.8371	22.7563	21.6747	20.5924
0.225	24.8708	23.7733	22.7055	21.6334	20.5680
0.230	24.7738	23.7112	22.6564	21.5974	20.5450
0.235	24.7397	23.6731	22.6239	21.5729	20.5167
0.240	24.6871	23.6437	22.6012	21.5509	20.5102
0.245	24.6663	23.6240	22.5854	21.5442	20.5082
0.250	24.6592	23.6204	22.5806	21.5405	20.5055